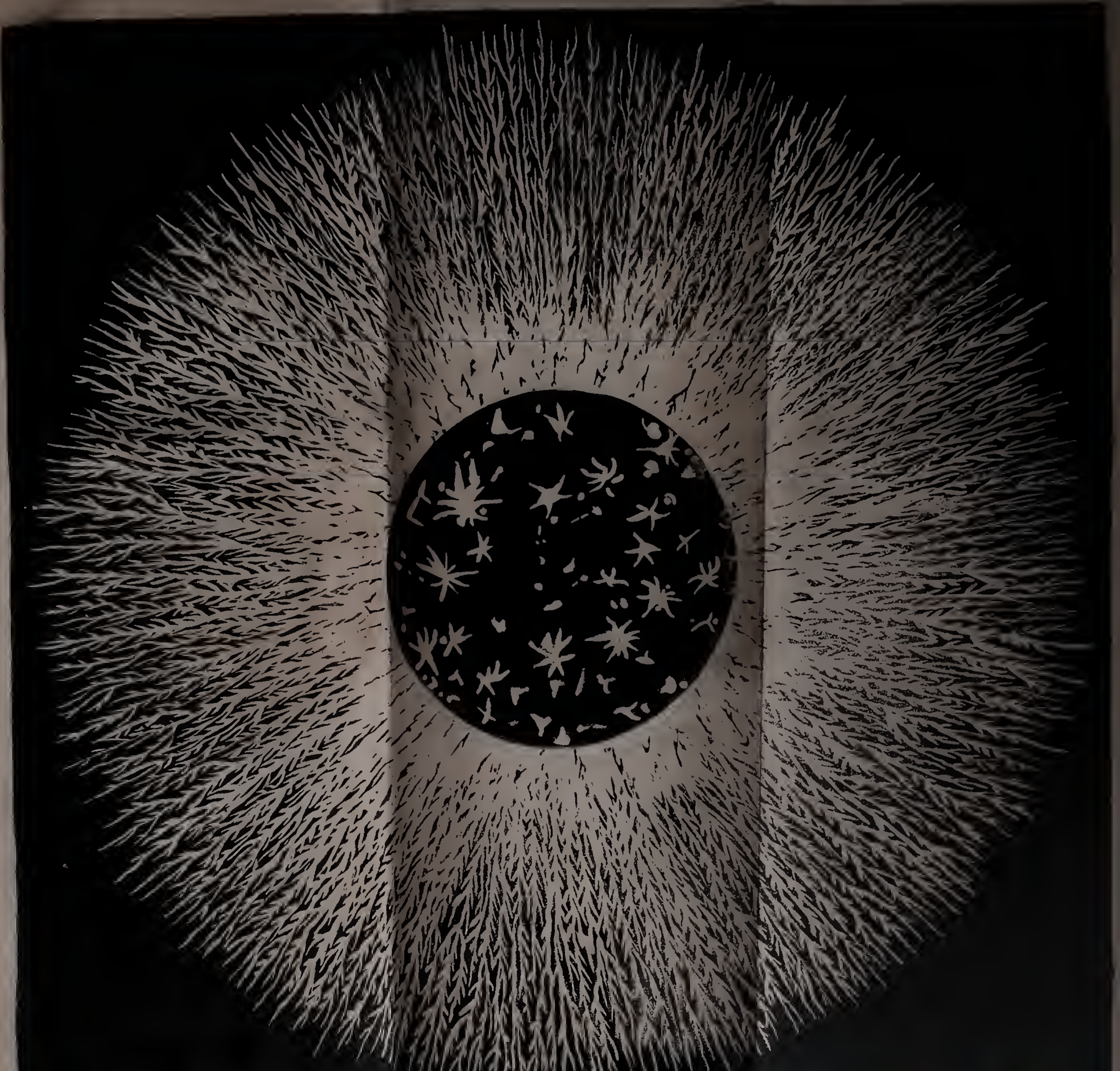

NEW EXPERIMENTS

ON

ELECTRICITY,

WHEREIN

THE CAUSES OF THUNDER AND LIGHTNING

AS WELL AS THE CONSTANT STATE OF

Positive or negative Electricity in the Air or Clouds, are explained;

WITH

Experiments on Clouds of POWDERS and VAPOURS ARTIFICIALLY DIFFUSED IN THE AIR.

ALSO

A DESCRIPTION OF

A DOUBLER of ELECTRICITY,

AND OF THE MOST

SENSIBLE ELECTROMETER YET CONSTRUCTED.

WITH OTHER

New Experiments and Discoveries in the Science,

ILLUSTRATED BY EXPLANATORY PLATES.

By the Rev. A. BENNET, F.R.S.
Curate of WIRKSWORTH, *Derbyshire.*

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1789

TO THE

REVEREND

Dr. RICHARD KAYE, F. R. S. & F. S. A.

DEAN OF LINCOLN,

AND

TRUSTEE

OF THE

BRITISH MUSEUM,

THIS

WORK

IS DEDICATED,

BY

HIS OBLIGED

HUMBLE SERVANT

ABRAHAM BENNET.

THE AUTHOR takes this opportunity of expreſſing his moſt ſincere thanks to his ſubſcribers, and eſpecially to the following ladies and gentlemen who have liberally encouraged his work, and recommended it to their numerous and reſpectable friends.

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INTRODUCTION.

INTRODUCTION.

BY the defire of fome of my friends I am induced to prefix a concife theory of Electricity, that the reader may more eafily comprehend the intention and ufe of the following experiments.

1ft. Electricity is an extremely fubtle fluid, which pervades metals with aftonifhing facility. It alfo pervades water, moift vegetables, animals, and many other fubftances more imperfectly. Thefe fubftances are termed perfect and imperfect conductors. But amber, glafs, filk, oil, dry air, and fome other bodies are impervious to the electrical fluid; and becaufe when rubbed they fhewed figns of electricity adhering to them, it was once fuppofed, that they were the only bodies which contained electricity, and were therefore termed electrics.

That fome bodies are conductors and others electrics or non-conductors does not appear to depend on their fpecific gravity; for gold is the beft conductor, and of the greateft fpecific gravity; and air, which is fo much lefs denfe, does not conduct; but charcoal is a good conductor, and lighter than glafs, which is an electric. It is not improbable but that this property may depend on the chemical affinity of their component parts with the electrical fluid. If electrics are fuppofed to have in their compofition a large quantity of fixed electricity as limeftone contains fixed air, they may be impervi-

ous

ous to any additional quantity of it, becauſe already ſaturated.

2dly. Electricity adheres to the ſurface of electrics much more ſtrongly than to the ſurface of conductors, and hence when two ſuch ſubſtances are rubbed together, part of the natural quantity of fluid belonging to the conductor adheres to the electric. Without this property of electricity its exiſtence might never have been diſcovered, but firſt on rubbing amber and then other electrics ſome of its effects were obſerved, and after gradual improvements the preſent electrical machines were conſtructed, and various other diſcoveries made.

3dly. Electricity is a very elaſtic fluid, ſo that it may be condenſed or accumulated upon any ſubſtance, whoſe connection with the earth is cut off by the interpoſition of an electric. This is termed inſulation. Electricity, thus accumulated, repels the natural electricity of the ſurrounding air, diſpoſing it to recede, which is then termed an electrical atmoſphere, whoſe denſity according to the demonſtration of the Earl of Stanhope, in his learned principles of electricity is proved to be in the inverſe ratio of the ſquare of the diſtance.

An accumulation of electricity which diſpoſes that of the ſurrounding air to be repelled is termed a poſitive electrical atmoſphere. But if the ſame inſulated body be deprived of its natural quantity of this fluid, it diſpoſes the ſurrounding air to abſorb more electricity, and this alſo produces an atmoſphere which is termed negative.

If

If light conducting ſubſtances as bits of gold leaf be brought within an electrical atmoſphere, they become attracted towards the electrified body: for the denſity of the electrical atmoſphere increaſes towards the centre, and the power of its attraction being proportionate to its denſity, whatever light conducting ſubſtances are immerſed in the extreme parts will move towards the centre till they touch the electrified body and receive a part of its electricity.

When the gold leaf has touched the electrified body, which thus attracted it, and has received from it a part of its electricity it becomes repelled; becauſe the ſuperinduced electricity will attract a quantity of air to form round itſelf another atmoſphere, whoſe electricity it tends to repel like the body which was firſt electrified, and therefore either the light ſubſtance will move off till it comes into air whoſe electricity is not repelled by the influence of the firſt electrified body, or a double quantity of air muſt be attracted into the ſame ſpace, or laſtly the intenſity of the electrical atmoſphere between the two bodies muſt diminiſh, which always happens when the two electrified bodies are immoveable. The ſame effects will take place whether the atmoſphere be poſitive or negative, for every ſubſtance has as ſtrong a tendency to abſorb its natural quantity of electricity, as it has to emit or diſſipate a ſuperfluous quantity. This explanation of electrical repulſion eaſily applies to the divergency of cork or pith balls or the ſtill lighter ſhreds of gold leaf uſed in the ſeveral kinds of ſenſible electrometers.

The

The electrical attraction and repulsion of light substances may be illustrated by cork balls or other light bodies swimming on water, which adhering round them is raised above or depressed below the common level, and causes the corks to be attracted towards or repelled from each other. When two cork balls are equally moistened and the adhering water is raised above the level surface, or when both the corks are dry and the surrounding water is depressed below the level surface, the corks are attracted, which may not seem to agree with the case of electrification, for two equally electrified bodies repel each other, but if two light bodies were electrified in a perfectly exhausted glass, where the air could not interfere, it is probable that they would not repel but attract each other, from the tendency in fluids to unite and form one globular mass, as two globules of clean quicksilver unite when brought into contact.

Repulsion [illegible] [illegible] take place [illegible] [illegible] exhausted air

Two light substances electrified in the open air repel each other, because their electricity strongly attracts the air, which coming between pushes them asunder, and in like manner the two corks swimming on water will be repelled, if one of them be made to raise its surrounding atmosphere of water above the common surface, and the other to depress it; for in this case the level surface may be considered as a third substance flowing in and attracted by each cork to complete its atmosphere, which pushes the corks asunder. This experiment may be conveniently tried, by pressing two bits of thin writing paper upon a round hole about half an inch in diameter

Repulsion of air [illegible] Electr. attracts [illegible] air [illegible] pushes [illegible] [illegible] asunder

meter, ſo as to make the paper concave; then let the edges be pared, and they will form two ſmall paper cups, which are to be placed upon the ſurface of a baſon of water; let a little fine ſand be put into theſe cups that the edges of the paper may be depreſſed below the level ſurface of the water, and then the two loaded cups will approach, and at laſt come into contact with each other, then let the edge of a moiſtened piece of paper be placed in the direction of a tangent line between the cups, and they will ſuddenly recede to the diſtance of ſeveral inches.

Every method of condenſing or rarifying the electrical fluid may be explained by the principle of adheſive attraction: but I ſhall here only mention the practical method of rubbing a ſtick of ſealing wax or rather a glaſs tube about five inches long covered with ſealing wax upon woollen cloth, for the purpoſe of trying the quality of electricity communicated to an electrometer. It is well known that the ſealing wax thus rubbed is excited negatively, that is the natural electricity of the ſealing wax is left upon the woollen, and its atmoſphere being brought ſo near as to touch the atmoſphere of the electrometer the gold leaf will either diverge wider or collapſe; if it diverges more, its electricity is negative like that of the ſealing wax; but if it collapſes, it is poſitive.

4thly. Electricity may be accumulated in a much greater degree upon one ſide of a thin electric as a plate of glaſs or a bottle, if the oppoſite ſide be connected with the earth by means of a conductor, for

as

as electricity is condensed on one side of the glass the natural electricity is rarified on the other, and the restoration of the equilibrium between the two sides, causes the effect termed an electrical shock, and that the fluid may be more speedily diffused over or discharged from the surface of the glass it is coated with tinfoil except near the edges. Fluid electrics may also be charged, but because the charge might otherwise soon break through, the two coatings must be farther distant from each other, except when the quantity of electricity is small. There is one remarkable difference between the charge of a solid and a fluid electric, which is, that the charge principally adheres to the surface of the solid electric and not to its coating: but when a plate of air is charged it adheres to the coating: on this consideration was founded the contrivance of the doubler of electricity hereafter described.

That some quality of accumulated electricity should act through electrics which are impervious to the fluid itself, and cause their natural electricity to expand so as to produce an electrical atmosphere; or repel the natural electricity on the opposite side of an electric in the case of charging the leyden bottle, are facts which have long been admired, and though most of the extraordinary effects of electricity depend on this property, yet I think it has never been very satisfactorily explained. If the elasticity of fluids in general was clearly understood, I doubt not but this difficulty would be surmounted, and if the opinions of Des Cartes on this subject were verified by experiments

periments they might gain credit, notwithſtanding the general fallacy of his principles. "Rara cor-
"pora illa ſint, inter quorum partes multa inter-
"valla exiſtunt, corporibus aliis repleta. Ut cum
"videmus ſpongiam aqua vel alio liquore turgentem.
"Etſi cum aer aut aqua ſit rarefacta, non videamus
"ullos ipſorum poros qui ampliores reddantur, nec
"ullum novum corpus, quod ad illos replendos ac-
"cedat; non eſt tamen rationi tam conſentaneum,
"aliquid non intelligibile effingere, ad eorum rare-
"factionem verbotenus explicandam, quam ex hoc
"quod rarefiant, concludere, in ipſis eſse poros,
"ſive intervalla quæ ampliora redduntur, & novum
"aliquod corpus accedere, quod ipſa implet; etſi
"hoc novum corpus nullo ſenſu percipiamus.
"Nulla enim ratio nos cogit ad credendum, cor-
"pora omnia quæ exiſtunt debere ſenſus noſtros
"afficere."

Des Cartes Prin. Philos.
Par. 2. Sect. 6.

What is here ſaid of the rarefaction of air and water may be applied to the rarefaction of electricity, that is there appears no way of accounting for it but by the ſuppoſition of another fluid ſtrongly adhering to and mixed with it, and which is ſufficiently ſubtle to paſs thro' glaſs. On this hypotheſis it is eaſy to conceive ſuch mixed fluid accumulated in a bottle by the action of an electrical machine, and as the charge goes on and the fluid is condenſed by being forced into a leſs ſpace than it would

would otherwiſe occupy, the fluid which can paſs thro' glaſs is forced out and would rarify all the ſurrounding electricity, by uniting with it, like heat diffuſed amongſt colder bodies, but being every where inſulated, it is confined, except on the outſide of the bottle, where becauſe the ſurface is connected with the earth its electricity can paſs off. Light is ſo conſtantly emitted or excited by electrical ſparks and ſo readily paſſes thro' glaſs that it might reaſonably be ſuſpected to be combined with the electrical fluid and be the cauſe of its elaſticity, but ſome experiments do not ſeem to favour this ſuppoſition particularly ſect. 2d. Exp. 34.

By theſe few principles the chief effects of electricity as far as they are yet known may be in ſome meaſure explained; but it is impoſſible to acquire an adequate knowledge of it without an attentive performance of experiments: for altho' I believe electricity is entirely ſubject to the ſame laws with every other ſubſtance, yet becauſe it hath ſome qualities in a very high degree as ſubtilty, elaſticity and adheſive attraction, and others ſcarcely at all as gravitation and ſolidity, it is very difficult without experiments to become impreſſed with a juſt notion concerning them.

Since the performance of experiments is ſo neceſſary to thoſe who wiſh to acquire a more accurate knowledge of electricity, I beg leave here to ſuggeſt that the gold leaf electrometer, may without partiality to my own contrivance, be recommended, as the firſt inſtrument to be uſed, and the contents of the

Gold leaf
Electr.
recommend

the following sections may serve for introductory lessons as well as any other. And if the more laborious and troublesome part of the science shou'd not be approved, there is sufficient scope for instructive varieties in the use of the electrometer and doubler without more cumbersome machinery, so that the author hopes, that ladies as well as gentlemen, who have honoured him with their patronage, will here find some amusement.

New Experiments, &c.

SECTION I.

Defcription of a gold leaf electrometer.

THIS inftrument principally confifts of two narrow flips of gold leaf fufpended in the middle of a hollow cylindrical glafs.

The foot A plate 1, may be made of metal or wood, and about three inches high, that there may be convenient room to handle the inftrument without touching the glafs. The cylindrical glafs B in which the gold leaf is fufpended may be about five inches high, and two inches in diameter. The cap C is made of metal, and flat on the top, that the various fubftances whofe electricity is to be examined may be conveniently placed upon it. The diameter of the cap is about an inch more than that of the glafs, and its rim D is about an inch broad and hangs parallel to the glafs to keep it clean and dry. Within this is another circular rim about half as broad as the other, made to go over or within the glafs, and is therefore lined or covered with leather, or other foft fubftance, to make it fit clofe, and thus the

the cap may be eafily taken off to repair any accident happening to the gold leaf. Within this rim and in the centre of the cap a tube is fixed, wherein the peg E is placed. To the peg, which is made round at one end and flat at the other, two flips of gold leaf F are faftened with pafte, gum water or varnifh.

If gold leaf is ufed it may be fhorter than filver leaf. The gold is much more fenfible, but the filver is eafier to cut and lefs liable to be accidentally torn. I have moftly ufed gold about two inches long, tapering to a fine point and faftened to the peg at the broad end. The breadth of the upper end of the gold is about one fifth of an inch, which keeps the flips more exactly parallel, and the electrical repulfion is more fenfible when the points are narrow, as I have obferved when an accidental very narrow flip hung by the fide of two parallel ones, the narrow flip always moving firft.

Without the glafs the gold leaf would be fo agitated by the leaft motion of the air that it would be entirely ufelefs, and if electricity fhould be communicated to the fides, the gold would be attracted and torn, therefore two pieces of polifhed tinfoil G H are faftened with varnifh on oppofite fides of the internal furface where the gold leaf may be expected to ftrike, and are connected with the foot of the electrometer. The breadth of the tinfoil at the foot is one fourth of the circumference of the glafs, and it terminates in a point towards the cap, about as high as the peg to which the gold leaf is faftened. It is

broad at the bottom, becauſe there the points of the gold leaf are moſt liable to ſtrike the glaſs, and being made narrow upwards does not prevent the repulſion from being eaſily obſerved.

Theſe ſlips of tinfoil, not only carry off ſuperfluous electricity, but ſerve other important purpoſes, as will appear from theſe two experiments.

EXPERIMENT I.

Upon a ſuppoſition that the gold leaf was attracted by the tinfoil, I ſuſpended it in the open air, without a glaſs, and when electrified I brought two wires near it, and the gold leaves open'd wider, till they touched and collapſed, then upon bringing the wires ſtill nearer they again diverged, which proved that the two pieces of tinfoil were uſeful to increaſe the ſenſibility of the inſtrument.

EXPERIMENT II.

I faſtened the gold leaf to the inſide of an iron mortar hanging by a ſilk ſtring with the mouth downwards, and though I communicated to it as much electricity as it would receive, the gold leaf did not diverge till a wire was introduced, which firſt cauſed the points to open, and then the higher part of the gold, as the wire came nearer to the place where the gold was faſtened. This experiment ſhews that the tinfoil takes off the influence of the cap which would otherwiſe diminiſh the repulſion of the gold leaf.

The upper end of the glaſs is covered and lined with ſealing wax, at leaſt as low as the outermoſt rim,

to

to render its insulation more perfect, for sealing-wax does not collect moisture from the air so soon as glass. In performing this operation, the glass shou'd be gradually heated over a candle till it will cause the wax to flow uniformly over the surface, for if it be covered whilst the glass is cooler than the wax it will not insulate so perfectly. The foot may be about three inches and an half in diameter at the bottom, that the instrument may stand sufficiently firm.

An electrometer of this kind has been carried from Birmingham to London; another from Wirksworth to York, and a third from Wirksworth to Etruria in a portmanteau on horseback, yet without injury; it is therefore easy to make electrometers less in every dimension, especially in diameter, whereby their sensibility is increased, and inclose them in a proper case to carry in the pocket, to observe the atmospheric electricity whilst on a journey, or on the top of a mountain. For some purposes it may be also necessary to make them larger. In many experiments I have used one about five inches in diameter, which shew'd the changes in the atmospheric electricity more distinctly than a smaller electrometer whose gold leaf would sooner strike the sides.

The broad cap of this large electrometer was also very convenient for placing upon it red hot crucibles or vessels of water in experiments on evaporation.

SECTION II.

Experiments on clouds of powders and vapours artificially diffuſed in the air, and other experiments illuſtrating the principles of electricity, and ſhewing the great ſenſibility of the gold leaf electrometer.

EXPERIMENT I.

POWDER'D chalk was put into a pair of bellows and blown upon the cap of the electrometer, placed at the diſtance of about ſix inches, which electrified it poſitively. See plate 3 fig. 7.

EXPERIMENT II.

Powder'd chalk was blown from the bellows towards the electrometer placed at the diſtance of three feet, which cauſed the gold leaf to diverge negatively.

EXPERIMENT III.

The cap of the electrometer was moiſtened, and the powder'd chalk blown upon it at the diſtance of ſix inches, which electrified it negatively, contrary to the dry cap at the ſame diſtance.

EXPERIMENT IV.

Two electrometers were placed with their caps about an inch aſunder, the one moiſt and the other dry, and a ſtream of powder from the bellows at the diſtance of ſix inches was made to paſs between the caps, which electrified the one poſitively, and the other negatively.

EXP.

EXPERIMENT V.

If a bunch of wire, feathers, or ſilk, were placed in the bellows, the electrometer was negatived at the ſame diſtance which produced a poſitive ſtate without them; alſo blowing gently with the bellows without the iron pipe, (by which means the powder was more widely diffuſed in the air) had the ſame effect.

EXPERIMENT VI.

A red hot ſtone was placed upon an inſulating ſtand connected with the electrometer, and when powder'd chalk was blown upon it from the bellows within the diſtance of ſix inches, it became ſtrongly and permanently negative.

EXPERIMENT VII.

If the perſon who blows the powder'd chalk into the air from the bellows be inſulated by ſtanding upon a ſtool with glaſs feet, and after blowing touch the cap of the electrometer, the gold leaf will diverge poſitively.

When the bellows produced poſitive electricity on the dry cap, or negative on the moiſt one, the cap was permanently electrified: but the negative ſtate of the powder, blown at the diſtance of three feet, was not communicated; the gold leaf collapſing as the powder paſſed away.

Since the moiſt cap or hot ſtone produce a negative ſtate of electricity within ſix inches, the one by detaining the powder, and the other attracting its

electricity by means of hot effluvia, it appears that the whole ſtream is properly negative: but the powder continues to depoſit electricity as it paſſes out of the bellows, and tho' it has loſt ſome in its way, yet it will electrify the cap poſitively whilſt thus in the act of changing its ſtate.

To exemplify this let two metal balls be inſulated, and let one of them receive a ſpark, then bring it near the ſecond ball, and it will cauſe the natural electricity of this ſecond ball to paſs off and electrify any ſubſtance touching it poſitively, and this ſecond ball is left properly negative: but let the firſt ball approach nearer, and notwithſtanding its negative ſtate, the ſecond ball will ſtill communicate poſitive electricity. By this example it is evident that the powder may communicate poſitive electricity whilſt under the influence of ſome cauſe which renders it negative; this cauſe I ſuppoſe to be the contact of air, which has a greater or leſs affinity with the electrical fluid than the powder, and therefore when it is ſuddenly projected into the air, each particle is diſpoſed by this contact of air to abſorb or emit electricity as it leaves the earth, and in paſſing along, the chalk depoſits electricity upon the dry cap, whilſt the ſame powder is acquiring a negative ſtate.

EXPERIMENT VIII.

When the air is not too dry, or when the electrometer has been kept in a damp place, let the gold leaf be made to diverge by holding excited ſealing wax near it, and let it continue thus diverging about

half

half a minute, then ſuddenly remove the ſealing-wax and the gold leaf will firſt collapſe, and then open with a contrary ſtate of electricity. This I ſuppoſed wou'd have explained the poſitive cap above-mentioned: but when a ball of metal was inſulated in dry weather by a warm tube of glaſs cover'd with ſealing wax, it became quickly and ſtrongly poſitive when the chalk was blown upon it within ſix inches.

EXPERIMENT IX.

A piece of chalk drawn over a bruſh ſo as to cauſe a cloud of powder to paſs over the cap of the electrometer, produces a negative repulſion of the gold leaf, but without communicating a negative ſtate of electricity.

EXPERIMENT X.

Powder'd chalk laid upon a metal plate placed upon the cap and blown off with the mouth or bellows, electrifies it permanently poſitive.

EXPERIMENT XI.

If a bruſh be placed upon the cap, and whilſt held with one hand the bruſh be rubbed with a piece of chalk till a conſiderable cloud of powder be raiſed, and then the hand removed, as the cloud diſperſes the gold leaf will diverge poſitively. Or if the cap of the electrometer be touched by one perſon whilſt another projects a cloud of powder'd chalk, the ſame effect will take place.

In

In this experiment a poſitive ſtate is cauſed by the influence of the negative cloud.

EXPERIMENT XII.

Powder'd chalk falling from one plate to another placed upon the electrometer, electrifies it negatively.

EXPERIMENT XIII.

A book was chalked upon the edge and ſuddenly clapped together, powder'd chalk was projected from a gooſe wing, and the electrometer was introduced into the duſt raiſed from the road by travellers, all which electrified it negatively: but when duſt was ſtruck up with a ſtick very near the electrometer it became poſitive, which agrees with exp. 1 and 2.

EXPERIMENT XIV.

Wheat, flour, oat-meal, and minium produce in every caſe poſitive electricity, where chalk and all other powders yet tried are negative; ſuch are red and yellow okre, rozin, coal aſhes, powder'd crocus metallorum, aurum moſaicum, black lead, lamp black, powder'd quick lime, umber, Spaniſh brown, powder'd ſulphur, flour of ſulphur, iron filings, ruſt of iron, ſand. Alſo powders made from dried decoction of dyers woods as well as metallic calces, on the ſuppoſition of their ſimilarity to flour or minium and other powders not regiſtered, but none of theſe laſt were poſitive.

EXP.

EXPERIMENT XV.

The inſide of the bellows pipe was moiſtened, but this did not alter the electricity of the powders blown thro', therefore its excitation does not appear to depend upon friction in the pipe.

EXPERIMENT XVI.

Air alone blown upon the cap does not electrify it, nor if blown thro' a hole made in a lump of chalk, whence it is not likely that the electricity is excited by friction againſt the air.

EXPERIMENT XVII.

A lump of chalk was inſulated and rubbed upon a bruſh faſten'd to the cap of the electrometer, in this caſe both the chalk and bruſh were poſitive, and the aſcending cloud of powder negative. Hence probably the excitation of the powder is not occaſioned by the friction of the chalk againſt the bruſh, ſince the ſtates of the lump and bruſh were not contrary.

EXPERIMENT XVIII.

Equal Meaſures and equal weights of powder'd chalk and wheat flour were mixed and projected from a bruſh, and the electricity of the chalk prevailed.

EXPERIMENT XIX.

Scales of iron were let fall from a plate a conſiderable height above the electrometer, which cauſed a cloud of duſt to ariſe from the lower plate, this lower plate was therefore electrified poſitively, contrary

trary to the ſtate it acquired by ſifting the powder or letting it fall more gently.

EXPERIMENT XX.

A lighted candle placed upon the electrometer very much increaſes its ſenſibility, and is peculiarly uſeful in collecting atmoſpheric electricity: but if the communicated electricity is not conſtantly ſupplied, it will alſo ſoon diſſipate its charge in the air.

EXPERIMENT XXI.

A ſmall tube of glaſs cover'd with ſealing wax was ſlightly excited, and tho' by the influence of its atmoſphere it cauſed the gold leaf to diverge conſiderably wide, it did not communicate its electricity even when brought ſo near as to touch the cap; but when a candle was placed upon the electrometer, the electricity was communicated at the diſtance of twelve inches or more, and when ſtrongly excited it cauſed a very ſenſible divergency at the diſtance of ſix feet.

EXPERIMENT XXII.

The electrometer with its candle was carried into a room juſt ſwept, and the duſt diffuſed in the air cauſed a very ſenſible negative repulſion of the gold leaf.

EXPERIMENT XXIII.

The electrometer with its candle was carried thro' a room adjoining to that wherein the electrical machine had been turned for ſome time before, (the door

door between the Rooms having been left open,) and the air was found very ſenſibly electrified. The fluid being diffuſed thro' the air of both rooms.

EXPERIMENT XXIV.

Take a quantity of powder'd chalk, and alſo a quantity of wheat flour, and put alternately the chalk and flour into the bellows, and blow the powder into the air a few times. It is then eaſy for another perſon bringing the electrometer with its candle into the room, to diſcover whether the chalk or flour was uſed, the chalk being negative and the flour poſitive. In like manner if chalk and flour be projected on different ſides of a room it may be diſcovered where the chalk and where the flour were uſed, or if they were mixed it will ſhew which prevails.

EXPERIMENT XXV.

No ſenſible electricity was produced by projecting water, ſalt, powder'd nitre, or allum, nor by ſmoke, flame, or exploſions of gunpowder.

EXPERIMENT XXVI.

If the ſmall end of a tobacco pipe be made red hot, and the pipe be fixed in a cloven ſtick, ſo that the ſtick may be eaſily placed in a ſmall hole in the cap of the electrometer, in ſuch a manner that the pipe may be directed towards another electrometer placed about four inches from the end of the pipe, upon putting ſome water into the pipe head, the ſteam

ſteam will ſuddenly iſſue out of the ſmall end, and electrify the firſt electrometer negatively, and the ſecond poſitively.

EXPERIMENT XXVII.

Spirit of wine, and ether, were tried with the hot tobacco pipe, and their electricity did not differ from water, but they required leſs heat. Oil and vitriolic acid produced ſmoke which was not electrified.

EXPERIMENT XXVIII.

Let a cullender or tin funnel be ſuſpended by ſilk, and put ſome hot coals in it. Upon throwing water on the coals the aſcending vapour will be found electrified poſitively, and the drops of water falling thro' upon the electrometer will be electrified negatively: but if a ſecond or third quantity of water be poured thro', the drops will ſometimes become poſitive, as will be found more fully tried in another ſection.

EXPERIMENT XXIX.

Poſitive electricity is produced by blowing with one's mouth thro' a red hot tobacco pipe upon the cap of the elctrometer, by the rarefaction of moiſture contained in ſuch air: but dry air blown thro' from clean dry bellows does not electrify it.

EXPERIMENT XXX.

Vapour of water was drawn into the valve of the bellows and blown upon the electrometer thro' the iron

iron pipe, yet its poſitive electricity was not deſtroyed by thus paſſing thro' the bellows.

EXPERIMENT XXXI.

If a ſmall lantern with a candle in it be placed upon the cap of the electrometer, and expoſed to the air in an open place, or not too near high buildings, or trees, it ſeldom fails to render the atmoſpheric electricity very ſenſible.

EXPERIMENT XXXII.

The electrometer was carried into the middle of a field when the weather was clear and froſty, and a ſmall lantern placed upon it, cauſed the gold leaf to ſtand open with poſitive electricity about an inch wide, and when carried up a mount about ſix feet higher the gold leaf ſtruck the ſides; but it gradually collapſed as it came near trees or houſes.

EXPERIMENT XXXIII.

A veſſel of water was placed upon an inſulating ſtool in the open air, when the weather was dry and clear, then ſtanding upon the ſame ſtool I ſpouted water as high as I cou'd with a ſmall ſyringe about ſix times, then upon touching the cap of the electrometer with my finger, the gold leaf opened poſitively; the atmoſpheric electricity from a higher ſtratum of air having charged my body thro' the ſtream of water.

EXP.

EXPERIMENT XXXIV.

Red hot glaſs was brought very near the electrometer and the focus of a concave mirror made to fall upon the cap, neither of which haſtened the diſſipation of its electricity. Red hot iron draws it off, but not ſo far as flame.

EXPERIMENT XXXV.

An iron mortar was placed upon the electrometer and red hot cinders were dropped into it whilſt electrified poſitively or negatively, but this did not diminiſh the divergency of the gold leaf. Bodies of equal ſurface but different in maſs, when placed in the ſame circumſtances are equally charged with electricity, according to the experiments of M. Achard, therefore various ſubſtances may be introduced into the mortar or other hollow veſſel placed upon the cap of the electrometer, without adding to the quantity of electrified ſurface, which may be uſeful in trying various chemico-electrical experiments.

EXPERIMENT XXXVI.

If the electrometer be charged with a ſmall quantity of electricity, and the ſharpeſt pointed needle or edge of a razor be brought within the leaſt viſible diſtance towards the cap, it will not draw off its electricity, but flame draws it off at a conſiderable diſtance.

This experiment ſhews that ſharp points or edges need not be avoided in the conſtruction of this inſtrument, or of the doubler, or atmoſpheric apparatus

ratus defcribed in the following fections, and that a flame is better than a pointed wire for the purpofe of collecting atmofpheric electricity.

EXPERIMENT XXXVII.

A very light pith ball was put upon the end of a very fmall wire, and the wire was fufpended by a ring to the prime conductor of the electrical machine; alfo a wire of the fame length, but without any pith ball, was fufpended in a fimilar manner, and both were repelled by the electricity communicated to the conductor; but the wire with the pith ball defcended firft, which alfo fhews that it is more neceffary to make the electrometer light than to avoid points and edges.

EXPERIMENT XXXVIII.

A fmall pin was faften'd upon the end of a ftick of fealing wax and charged with electricity, which was communicated from the pin to a metallic infulated conductor, fifteen inches in diameter, and feven feet long, whofe furface was therefore prodigioufly larger than that of the pin, yet its electricity caufed a very fenfible divergency of the gold leaf. This not only fhews the fenfibility of this electrometer; but affifts our conception of the amazing divifibility and elafticity of this wonderful fluid.

[A defcription of the gold leaf electrometer and moft of the above experiments, are printed in the philofophical Tranfactions for the year 1787.]

SECTION III.

New experiments with M. Lichtenburg's *large electrophorus.*

THE following experiments are intended as improvements on M. Lichtenburg's beautiful configurations, firſt made on a reſinous electrophorus by drawing over it the knob of a charged phial, and render'd viſible by ſifting powder'd roſin over the plate, which falling ſo differently according to the circumſtances in which the experiment is made, exhibits the diffuſion of electricity in a very pleaſing manner.

My firſt electrophorus was a glaſs plate fifteen inches ſquare, cover'd on one ſide with a thin reſinous black coating, with tinfoil paſted on the other ſide; for if the ſide oppoſite to the reſinous one be not a conductor, the electrical fluid will not be eaſily diffuſed over it. Glaſs was uſed that the electricity might not be ſo liable to paſs thro' the ſmall holes and bliſtered places which cannot well be avoided if the reſinous ſubſtance be thinly ſpread upon wood or metal.

As powder'd roſin projected from a bruſh is negatively electrified, there appeared no doubt but that chalk and other powders, which by the ſame means are negatively electrified, would anſwer as well or better; ſuch powders were therefore tried and found to ſucceed remarkably well.

EXP.

EXPERIMENT I.

The plate was ſuſpended by a loop againſt a wall that the groſſer part of the powder might fall to the ground, and no more adhere to the plate than was attracted by the electricity diffuſed thereon. A ſmall phial was charged very weakly by one revolution of the electrical machine, and after its knob had been drawn over the reſinous plate, a cloud of chalk was projected by rubbing the lump upon a bruſh near the electrified ſurface of the plate, this produced a plain white line without any ramifications.

EXPERIMENT II.

When the phial was charged by three revolutions of the machine, ramifications appeared upon the plate at a conſiderable diſtance from each other.

EXPERIMENT III.

Five or ſix revolutions cauſed the electrical fluid to ſpread upon the plate in ramifications very near each other. Cloſe to each branch a ſmall ſpace was left uncover'd with powder, forming a kind of ſhade to the figure. Beyond this ſhade the powder lay ſmooth, ſoftening off externally.

EXPERIMENT IV.

With a very ſtrong charge the ramifications were cloſe and broad, reſembling white feathers with a very broad ſhade.

EXPERIMENT V.

A large jar was charged as full as it wou'd hold and its knob drawn over the refinous plate, the middle of the figure was about an inch broad, and moftly plain and white, the fhades were now more confpicuous than the branches, and dark irregular ftreaks interfected the diftant white fpace.

EXPERIMENT VI.

When a bottle with a large wooden knob in it was highly charged, and its knob carried at the diftance of an inch from the plate in a direction acrofs it, the figure produced had no ramifications, but feveral cloudy white ftreaks appeared; thefe ftreaks vary their figure every time the experiment is tried.

EXPERIMENT VII.

When a figure was made upon the plate by drawing with a moift finger, and the moifture touched with the knob of the charged phial, the ramifications darted from the fides of the figure in a perpendicular direction; whereas the ramifications made by fliding the knob over the plate iffued from the middle of the figure, floping like the branches of a tree. The reafon of this difference is plainly that in the firft cafe each ramification is made at the fame time, and in the latter the firft branch repels that which is made after it, and thus prevents it from darting perpendicularly.

EXPERIMENT VIII.

A ſmall wire was laid upon the plate and an electrical ſhock made to paſs thro' the wire, which was then thrown off without being touched; in this caſe, when the chalk was projected, the ramifications appeared very diſtinct and long but not ſhaded, and their direction was perpendicular to the figure. A moderate charge produced longer ramifications than a very ſtrong one.

EXPERIMENT IX.

A circular braſs plate with an inſulating handle was placed upon the reſinous plate, and a ſpark from the charged bottle was communicated to the braſs plate which was then taken off by its inſulating handle, and chalk projected, which produced a very regular circle of ramifications about four inches long, proceeding from the circumference of the ſpace cover'd by the braſs plate, and within the circle were a number of irregular figures ſomewhat like ſtars. A ſhock made to paſs thro' the ſame plate generally produced more diſtinct ramifications, and ſometimes without any ſtars within the circle; and if the braſs plate was drawn along towards the edge of the electrophorus whilſt touched with the knob of the phial a very beautiful figure was produced.

EXPERIMENT X.

The reſinous plate was faſtened to the top of the pillar which ſupports and inſulates the cuſhion of the

electrical machine, and whilst the wheel was turning a brass knob was drawn over the plate, which produced very large and fine ramifications. A point drawn over, produced a figure very much resembling a white ostrich feather.

EXPERIMENT XI.

The plate remaining on the pillar as in the last experiment, a candle was brought very near the middle and immediately again removed. When chalk was projected, a circular space about twelve inches diameter was cover'd with powder, having a dark shade round it, beyond which the powder fell more thinly.

EXPERIMENT XII.

The plate was fastened to the prime conductor, and when the candle had been presented towards the middle as before, the chalk fell mostly on the outside of a circle of the same dimension.

EXPERIMENT XIII.

The phial was charged weakly negative and drawn over the plate which produced a plain line, but with chalk it was often black upon a white ground, contrary to the positive line. With wheat flower the line was as white as the positive one. Projected chalk being negative, and wheat flower positive, they wou'd always be only attracted by those figures whose electricity is contrary, but there is reason to believe that some of the projected powder

is

is either not electrified or poſſeſſes a ſtate contrary to the reſt, and therefore falls into the figure, but the difference of the powders is very conſpicuous.

EXPERIMENT XIV.

The phial was charged ſtrongly negative, and drawn over the plate. The figure was not ramified but conſiſted of a number of roundiſh ſpots, the largeſt about the ſize of a pea, with ſmaller ſpots between the large ones, the figure was ſhaded, and the ſpace beyond cover'd with powder as in the poſitive experiments.

EXPERIMENT XV.

A phial ſtrongly and negatively charged was drawn over the plate, and afterwards a pointed wire held in the hand only, was drawn over the ſame figure, then chalk was projected, which produced a beautiful ramified figure in the middle of the negative one.

EXPERIMENT XVI.

A conical tin funnel was placed with its baſe on the middle of the reſinous plate, and a negative ſtrong charge given by connecting the diſcharging rod with the under ſide of the plate, then a poſitive charge was given in the ſame manner, the funnel was thrown off and chalk projected, which produced very beautiful ramifications both within and on the outſide of the circle.

EXPERIMENT XVII.

A phial was charged poſitively, and placed with its knob about half an inch diſtant from the middle of the plate. Whilſt the phial ſtood in this ſituation chalk was projected, which adher'd ſmoothly to the knob of the phial, and to the ſurface of the plate for the ſpace of about 9 inches diameter, every where cover'd except a very diſtinct circular ſpot about three inches diſtant from the knob, if the chalk was projected at ſeveral intervals, the ſucceſſive projections, did not come up to the edge of the firſt circle, but fell round a larger circumference and not quite parallel to the firſt. A negative charge produced the ſame kind of ſpot. The cauſe of theſe ſpots was found to be electricity ſtreaming thro' the air from the cork in the neck of the phial, for a wire placed in the cork near that which ſupported the knob alter'd the ſhape of the ſpot. The reaſon that it was left entirely without powder tho' occaſioned by the communication of electricity, will appear in a ſubſequent experiment.

EXPERIMENT XVIII.

A knob of wood about an inch in diameter was placed upon the wire of a phial which was charged highly poſitive, and the knob drawn over the plate ſo as to touch the ſurface, this produced a beautiful figure, the middle of which was ſmoothly cover'd with chalk, and the ſides finely ramified with ſhades.

EXP.

EXPERIMENT XIX.

A braſs knob about three inches in diameter was placed upon the phial inſtead of the ſmall one, and a ramified figure drawn with it upon the middle of the plate; then, before chalk was projected, the knob with the remaining charge was placed oppoſite to the figure at the diſtance of about half an inch. In this caſe the powder fell upon the knob, and on the outſide of the figure, leaving its ramifications clean and diſtinct, but entirely without powder.

EXPERIMENT XX.

A ſmall candle was inſulated and its flame placed about an inch diſtant from the middle of the reſinous plate, then the knob of a poſitively charged phial was ſuddenly brought to the flame, and both the flame and phial inſtantly taken away again. In this experiment when the chalk was projected a circular ſpace about four inches in diameter was clean and free from powder, the reſt of the plate was cover'd, except a great number of ſmall circular or elliptical ſpots, which ſhews that the electrical fluid paſſed to the plate in detached balls like ſome atmoſpheric meteors, or the plate abſorbed from the air a contrary ſtate of electricity, which produced this appearance.

EXPERIMENT XXI.

If a poſitive figure be firſt drawn and then a negative one acroſs it or v. v. when the powder is projected it is eaſy to diſtinguiſh which was firſt drawn,

drawn, the ſecond appearing to cover the firſt, and when the poſitive figure is made laſt, the ramifications at the place of junction extend farther than the reſt and are left without powder. But if both the ſtrokes are poſitive or negative the firſt will appear to cover the ſecond.

EXPERIMENT XXII.

If powders of different colours are mixed and projected over the figures, ſome of the colours will prevail on the middle and ſome on the outſide, and eſpecially if two figures whoſe electricity is contrary are made on the ſame plate, and moſt of all when both the electrical ſtates of the figures and powders are contrary: for example, if minium whoſe electricity is ſtrongly poſitive, and ſulphur very ſtrongly negative be pounded together, and then this mixed powder put into the bellows, and blown upon the contrarily electrified figures, the powders ſeparate and the ſulphur falls on the poſitive figure and the minium on the negative. This produces a very pleaſing effect. I had often tried the experiment by projecting the powder from a bruſh: but the bellows do it much better, which laſt method was communicated to me by the Chevalier Landriani, who had ſeen it tried in Italy.

EXPERIMENT XXIII.

In ſome of the above experiments, when the reſinous plate was poſitively electrified by drawing over it the knob of a charged phial, and chalk projected,

jected, the middle of the figure was covered with a plain ſtreak of powder, or (if the charge was weaker) with beautiful white ramifications reſembling flowers; round theſe ramifications there appeared a dark ſhade very exactly defined, whereon no powder fell, and next to this the powder fell ſmooth, diminiſhing in thickneſs towards the edge of the plate. On the firſt view of theſe appearances, I ſuppoſed that the poſitive electricity depoſited upon the plate in the middle of the figure had render'd the ſhaded part of the ſpace negative, and that therefore alternate ſpaces were poſitive and negative: but upon placing a wire in the cap of my electrometer, and drawing it over the plate in various directions, and ſometimes covering different parts of the figure whilſt others were tried I could never diſcover any ſigns of a negative ſtate of electricity. The whole plate appeared poſitive, its intenſity diminiſhing from the middle of the figure.

EXPERIMENT XXIV.

Not perfectly convinced of the entire poſitive ſtate of the electrified plate by examining with the electrometer, I cemented a wire to the end of a glaſs tube covered with ſealing wax, in ſuch manner that the two ends extended each way like the points of a pair of compaſſes, then taking hold of the glaſs tube, I placed one end of the wire in the middle of a poſitive figure, and the other end upon a clean part of the plate, and drew the wire in the direction of the figure, keeping the firſt point in the

the middle. Upon projecting chalk where the point had touched the clean part of the plate, ſhaded ramifications appeared which plainly ſhewed the middle of the figure to be ſtrongly poſitive, as might be expected.

EXPERIMENT XXV.

A poſitive figure being drawn as above, the white part in the middle was carefully wiped off with my finger, ſo as to diſcharge its electricity, then the wire was placed with one point in the ſhaded ſpace and drawn along the figure. Upon projecting chalk over the clean part of the plate poſitive ramifications were produced as before, but much weaker.

EXPERIMENT XXVI.

The white ramifications and ſhades were both wiped off, and the wire placed near the edge of the ſmooth white ſpace, and with the other point on the clean part of the plate, and upon projecting chalk there was no figure produced: but if the wire was drawn in the ſame manner without wiping off the ſhaded part, a white line appeared with very few points like thorns, which ſufficiently proved that it was weakly poſitive; and hence it appears that it was the natural electricity of the plate diſpoſed to attract powder by the influence of that which was communicated in the figure.

EXP.

EXPERIMENT XXVII.

The white ramifications in the middle of the figure were wiped off and then more chalk projected upon the ſhaded part which cauſed the ramified points to extend farther, and by wiping off ſtill more and projecting chalk again, almoſt the whole of the ſhaded part was filled, which proves that this laſt ſpace is left uncover'd, becauſe the ſtronger electricity in the middle of the figure attracts all the powder which might otherwiſe fall in that ſpace. And in many other experiments it is found that various parts of the ſame plate will be filled with powder or left clean, where the ſame ſtate of electricity, but of different degrees of intenſity, has been communicated, particularly exp. 3, 4, 5, 17, 18, and 19.

EXPERIMENT XXVIII.

Glaſs plates were cover'd with red or black ſealing wax, and figures drawn upon the wax, then powder'd ſealing wax, or other powders which wou'd not loſe their colour by heating, were projected upon a plate of the oppoſite colour, and by holding the plates before a fire or over a candle till the ſurface was ſoftened, the figures were indelibly fixed.

EXPERIMENT XXIX.

I have tried to take off the figures upon paper in various ways, and firſt projected lamp black, ivory black, powder'd rotten ſtone, vermilion, and many other powders, ſometimes mixing them with gum

gum arabic, and then laying over the plate a paper ſoftened in water, with or without gum arabic diſſolved in it, and in ſome experiments the figures came off very well, eſpecially with vermilion, but moſtly failed. I then tried the dry'd extract of dyers woods, and ſucceeded very well. And ſince ſeveral of my friends have expreſſed their deſire to be informed of the proceſs, I will deſcribe it as minutely as I can.

To make red figures, take a pound of raſped Brazil wood, put it into a kettle with as much water as will cover it, or rather more; alſo put in about an ounce of gum arabic and a lump of allum about as big as a large nut, let it boil about two hours, or till the water is ſtrongly coloured; ſtrain off the extract into a broad diſh, and ſet it in an iron oven, where it is to remain till all the water be evaporated, which with me was effected in about 12 hours; but this depends on the heat of the oven, which ſhou'd not be ſo hot as to endanger its burning. Sometimes I have boiled the ſtrained extract till it was conſiderably inſpiſſated before it was placed in the oven, that it might be ſooner dry.

When it is quite dry but not burnt, ſcrape it out of the diſh and grind it in a mortar till it be finely pulverized. In doing this it is proper to cover the mortar with a cloth having a hole thro' to prevent the powder from flying away and offending the noſe, and alſo to do it out of doors if the weather be dry and calm, that the air may carry away the powder neceſſarily eſcaping, and which otherwiſe

wiſe is very diſagreeable. When ground fine let it be ſifted thro' muſlin or a fine hair ſieve, returning the coarſer part into the mortar to be ground again. When the grinding and ſifting are finiſhed the powder is ready for uſe. The reſinous plate I have moſtly uſed was compoſed of five pounds of roſin, half a pound of bees wax, and two ounces of lamp-black, melted together and poured upon a board ſixteen inches ſquare, with ribs upon the edges at leaſt half an inch high, to confine the compoſition whilſt fluid, thus the reſinous plate was half an inch thick, which is better than a thinner plate, the figures being more diſtinct. After the compoſition is cold, it will be found covered with ſmall bliſters, which may be taken out by holding the plate before the fire, till the ſurface be melted, then let it cool again, and upon holding it a ſecond time to the fire, more bliſters will appear; but by thus repeatedly heating and cooling the ſurface, it will at laſt become perfectly ſmooth. Some plates were made ſmaller and the reſinous compoſition confined to the form of an ellipſis, a circle or eſcutcheon, by a rim of tin half an inch broad, and fixed upon a board.

The next thing to be done is to prepare the paper, which is to be ſoften'd in water, either by laying the pieces upon each other in a veſſel of cold water, or firſt pouring a little hot water upon the bottom of a large diſh, then laying upon it a piece of paper, ſo that one edge of the paper may lie over the edge of the diſh, to remain dry, that it may afterwards be more conveniently taken up. Then

pour

pour more hot water upon its upper ſurface. Upon this place another piece in the ſame manner, again pouring on more water, and thus proceed till all the pieces are laid in. By uſing hot water the paper will be more ſoftened in a few minutes than if it remains in cold water a whole day.

When the figures are to be made the reſinous plate muſt lie horizontally whilſt the electricity is communicated, if the experiment requires any thing to be placed upon the plate; but it is convenient afterwards to hang it up in a vertical poſition whilſt the powder is projected, leſt too much powder ſhould fall where it is not required.

A little of the powder may be taken between a finger and thumb, and projected by drawing it over a bruſh, or which is better, a quantity of powder may be put into the bellows and blown towards the plate. When the figure is ſufficiently covered with powder, let the plate be again laid horizontally upon a table, then take one of the ſoftened papers out of the water by its dry edge, and lay it carefully between the leaves of a book, preſſing the book together, and let it lie in this ſituation about half a minute. Then remove the paper to a dry place in the book, and preſs it again about the ſame time, which will generally be ſufficient to take off the ſuperfluous moiſture. Then take up the paper by the two corners of its dry edge, and place the wet edge a little beyond the figure on the reſinous plate lowering the reſt of the piece gradually till it covers the figure without ſliding, then lay over it a piece of clean

clean dry paper, and prefs it gently, let it remain a fhort time, and then rub it clofer to the plate with a cloth, or which is better, prefs it down by means of a wooden roller cover'd with cloth, taking care that the paper be not moved from its firft pofition. When the paper is fufficiently preffed let it be taken up by its dry edge, and laid upon the furface of a veffel of water with the printed fide downwards, by this means the fuperfluous powder will fink in the water, and the figure will not be fo liable afterwards to fpread in the paper. After the paper has remain'd on the water during a few minutes, take it up and place it between the leaves of a book, removing it frequently to a dry place. If it be defired that the paper fhou'd be fpeedily dry, let the book-leaves in which it is to be placed, be previoufly warmed, and by removing it to feveral places, it will be dry much fooner than by holding it near a fire, and without drawing the paper crooked. By the above procefs it is obvious that leather, callico, or linen, as well as paper, may be printed with thefe figures, and the effects of the diffufion of electricity upon a refinous plate be exhibited to thofe who have not leifure or inclination to perform the experiments.

The atmofpheric electricity with all its variations of intenfity, and changes from pofitive to negative are marked on a refinous plate by an ingenious machine of the Chevalier Landriani, which moves by a clock, and the figures made on the plate during his abfence will become vifible when powder is

projected. These figures may therefore be taken off by this process, and the state of a day's electricity in Italy be transmitted to England.

EXPERIMENT XXX.

Mr. Wedgwood proposed to fix the figures by projecting fine powder'd enamel, after the electricity was diffused upon porcelain, and then to bake the plate or vessel (thus ornamented) in the usual way. This experiment was tried at his house, and the figures were very well fixed; but the weather being then unfavourable, they were not so beautiful as might be expected. I have since made the figures with more success, but had not the opportunity of fixing them.

In this way the ramifications and shades may be indelibly fixed and preserved, without any diminution of their beauty.

EXPERIMENT XXXI.

Another way of preserving the figures is to make a resinous plate of a proper shape to be framed and covered with glass. After the figure is made and the powder projected, it is necessary to hold the plate over a vessel of hot water, that by means of the steam its electricity may be gradually discharged, for if it be covered immediately, the powder will fly off to the glass. In one experiment I painted a glass black on one side, then cover'd the painted side with brass leaf, and after heating it in the sunshine till all the moisture was expelled, I made

made the figures upon the uncoated ſurface, cover'd it with another glaſs, and placed it in a frame. When glaſs is made very dry the figures will be as diſtinct and beautiful as thoſe made upon a reſinous plate; but it is neceſſary to perform the experiment in dry weather, and to take care that the glaſs and knob of the bottle, with which the figures are drawn, be ſufficiently and equally heated, for if the knob be colder than the plate, moiſture will be condenſed and ſpoil the figure. In trying experiments with a glaſs plate, I obſerved that it was very difficult to deprive it of the electricity laſt communicated. I rubbed the ſurface with wet cloths, then rubbed water with my fingers upon the electrified parts, then dipped the plate in water, and after that held it over the flame of a candle, yet found that all theſe methods were inſufficient, the figures might ſtill be ſeen when the glaſs was dry, and chalk again projected. I then rubbed the glaſs with tallow, and cleaned it off with powder'd chalk, which ſucceeded better.

EXPERIMENT XXXII.

I placed the above deſcribed glaſs plate in the ſunſhine where it was kept hot, and dropped a little oil upon the middle, and upon touching the oil with a poſitively charged bottle, it flowed in very fine ramifications. I then touched another drop of oil with a negative bottle, which alſo cauſed it to flow in ramifications, which I cou'd not perceive to

differ from the poſitive ones, except that they did not extend quite ſo far.

EXPERIMENT XXXIII.

I rubbed a circular ſpace in the middle of the glaſs plate with water, and touched it with a charged bottle, then projected chalk which cover'd the moiſt ſpace with a plain ſmooth coating of chalk, I then dried it over the flame of a candle, which alſo diſcharged its electricity. On the middle of this white ſpace I dropped ſome oil, and upon touching it with the charged bottle it ſhew'd its ſpreading ramifications more plainly than in the laſt experiment. Alſo this plain white ſpace being touched with a poſitive bottle, (by chalk thrown off the ſurface) ſhews ramifications more diſtinctly filled with branches than thoſe made upon clean glaſs or reſin.

EXPERIMENT XXXIV.

The ſurface of a reſinous plate was melted and powder'd roſin ſifted upon it ſo as to make it very rough, this cauſed the figures to ſpread leſs than upon a ſmooth plate, ſo that the points of the ramifications came very near the edge without ſtriking off.

EXPERIMENT XXXV.

A poſitive figure was drawn upon a reſinous plate and chalk projected conſiderably longer than uſual, and then on examining the figure there appeared ſmall

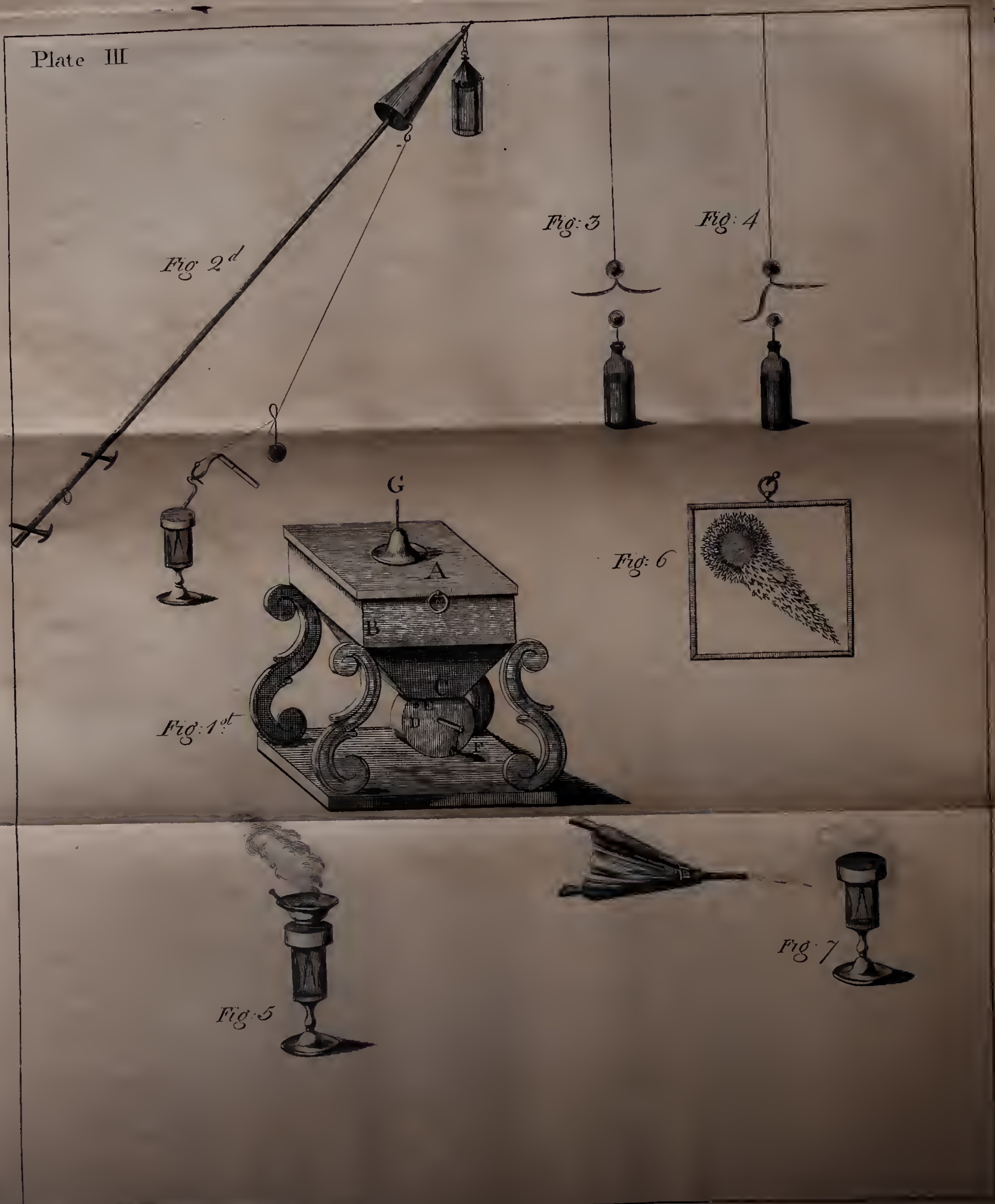


Plate III
Fig: 1st
A
B
C
D
F
G
Fig. 2d
Fig: 3
Fig: 4
Fig: 5
Fig: 6
Fig. 7

ſmall ramified vegetations like thoſe produced upon camphire by M. Moſcati. Alſo negative figures with flour produced the ſame.

EXPERIMENT XXXVI.

The powders made from the decoction of woods deſcribed in exp. 29. are very troubleſome when projected in the open air, and a conſiderable quantity is loſt in every experiment. I therefore contrived to project the powder by means of a circular bruſh incloſed in a box. Its lid A. plate 3d. fig. 1. is ſixteen inches ſquare, with edges about an inch and a half deep. The reſinous compoſition is poured within theſe edges of the lid to the depth of half an inch. The ſides of the box as far as the perpendicular part at B. are ſix inches deep; the ſloping boards at C. ten inches. The circular box D. in which the circular bruſh is incloſed is ſix inches diameter, and three inches thick. A wire or ſmall glaſs tube is put thro' the circular box at E. that the hairs of the bruſh when turned round by the handle F. may flirt againſt it and project the powder thro' an opening at C. and diffuſe it into the air contained within the box, and thus the figures made on the reſinous plate within the lid will attract the fineſt part of the powder, or that which is moſt ſtrongly electrified with the contrary ſtate to that of the figure, and the reſt will fall down again. If the box contains too little powder it will be neceſſary to lean it on one ſide, and if there be a large quantity, the bruſh muſt be turned ſlowly leſt it ſhou'd throw up too much. Smaller reſinous

plates may be ſupported within the box by bars of wood placed acroſs, and cover'd over with the lid whilſt the powder is projected.

EXPERIMENT XXXVII.

That I might more conveniently draw a variety of figures as well as try the effects of a very ſmall Leyden bottle, I made an electrical pen, by ſilvering the inſide and gilding the outſide of large thermometer tubes, from three to eight inches long, with and without bulbs, covering the ends with ſealing wax. In one end was fixed a blunt needle connected with the internal metallic ſurface. Some were coated on the outſide with tin foil, and a wire ſerved for the internal coating. Whilſt drawing with them, a charged bottle ſtands ready to ſupply electricity by touching its knob with the point of the needle. Small or large knobs, camel hair pencils, thiſtle down, and other ſubſtances occaſionally fixed on the point, produce different effects, and with the ſmalleſt pen lines may be drawn as fine as can be made with ink.

EXPERIMENT XXXVIII.

For the purpoſe of making circles, ſpiral lines, volutes, &c. an iron pin is fixed to the conducting ſide of the lid of the projecting box at G. plate 3 fig. 1; and when electricity is to be communicated to the reſinous ſurface, the pin is placed in a hole made in the table, and the plate whirled round, whilſt it is touched with the knob of a charged bottle,

bottle, or pen deſcribed above, ſo as to produce the required figure.

EXPERIMENT XXXIX.

The figure mentioned at the end of exp. 9th, made by drawing the braſs plate towards the edge of the electrophorus, by its inſulating handle whilſt the plate was touched by the knob of a charged bottle, ſomewhat reſembles the picture of a comet; but in the tail I frequently obſerved that a circular or elliptical ſpace was left without powder, which may reaſonably be attributed to the abſorption of a contrary ſtate of electricity from the air, which weakens the intenſity of the charge diffuſed in that ſpace; ſee plate 3, fig. 6. An electrified cloud or ſtratum of air emits or abſorbs balls of electrical fire called meteors or falling ſtars, to which this experiment may bear ſome reſemblance.

EXPERIMENT XL.

A circular plate of wood 12 inches in diameter was covered with tin-foil, and furniſhed with an inſulating handle, this plate had alſo three feet of glaſs about an inch long, cover'd with ſealing wax. A reſinous plate half an inch thick and of leſs diameter than the wooden plate, was laid upon a table, and the wooden plate placed over it, its feet ſtanding upon the table on the outſide of the reſinous plate, ſo that the ſurface of the wooden plate ſtood about half an inch higher than the ſurface of the reſinous plate. The knob of a charged bottle was

 applied

applied to the wooden plate which was then removed. Upon projecting powder the ſurface of the reſinous plate was covered with circular elliptical and irregular ſpots and rings. If the charge was weak there appeared only ſmall round ſpots, but a ſtrong charge produced rings broader or narrower according to the ſtate of the air and ſtrength of the charge. After touching the wooden plate with a poſitive bottle, I ſometimes removed the plate a little from its firſt poſition, and then touched it with a negative bottle, and inſtead of a ſingle powder, the mixture of minium and ſulphur were blown upon the plate, as in exp. 22, which diſtinguiſhed the poſitive and negative rings by the yellow and red colours.

Upon examining theſe rings by the method deſcribed in exp. 24, it appeared that the whole ſpace included within the rings was covered with electricity; and yet the powder was only attracted by the edges of the ſpace, probably becauſe the intenſity of the middle is diminiſhed by the equally ſurrounding repulſion of the ſides.

The circles of green graſs called fairy rings are with great probability attributed to the effects of lightning. See Dr. Prieſtley's Hiſt. of Electricity, vol. 2. page 274, of which this experiment may be eſteemed a tolerable artificial imitation.

SECT.

SECTION IV.

Experiments in which electricity is condenſed or rarified by the evaporation of water from various ſubſtances.

IN a treatiſe on electricity by M. l'Abbe Hauy, I find that ſince M. Volta's diſcovery of electricity produced by evaporation of water from hot coals, Meſſrs. Lavoiſier and De la Place have remarked, that bodies paſſing from a ſolid or fluid ſtate into vapour, give unequivocal ſigns of poſitive or negative electricity. A large veſſel containing a quantity of iron filings was inſulated and connected with M. Volta's condenſer. Three parts of water and one of vitriolic acid were poured upon the filings, which cauſed a briſk effervesſcence, and a rapid diſcharge of inflammable air, and in a few minutes the condenſer became ſo ſtrongly charged that it gave a very ſenſible ſpark, and by the electrometer it was found to be negative. The production of fixed and nitrous airs had the ſame effect. Alſo chafing diſhes inſulated and filled with lighted coal produced very clear ſigns of negative electricity after the combuſtion of the coal. It appears that in theſe experiments, the ſubſtances evaporated carry away from the veſſels with which they are in contact, a part of their natural electricity. But when water was poured upon red hot iron pans the elec-

electricity was no more negative as in the former experiments, but decidedly positive. These experiments were communicated to the academy of sciences in the year 1781.

M. de Saussure has also tried many experiments of this kind by plunging hot iron and other metals in water, and pouring water into crucibles of iron, brass, copper, silver or porcelain. Sometimes he used distilled water, also spirit of wine and ether, and in these experiments the electricity was sometimes positive, sometimes negative, and sometimes neither.

M. de Saussure thinks that when the operation which converts the water into vapour, at the same time decomposes it, or the body with which it is in contact, it produces a new quantity of the electrical matter, and that the vessel used in the operation becomes positive, negative, or neither, according as the fluid produced is superior, inferior, or equal to that which is taken from the vessel by evaporation. An account of these curious experiments is contained in the second volume of M. de Saussure's travels over the Alps, page 227.

The gold leaf electrometer being well adapted to the performance of experiments of this kind, I was induced to repeat some of them with variations in hopes of new appearances. And since almost every substance in the whole chemical nomenclature may thus be subjected to the action of fire, and its affinity with electricity in a state of vapour examined,

ned, new facts may yet arise which will produce new theories, therefore the following experiments are placed in the order they were tried without regard to system.

EXPERIMENT I.

A bason of tinned iron about six inches wide at the bottom, and eight inches at the top, was placed upon the cap of a gold leaf electrometer. The bottom of the bason was cover'd with water about an inch deep. An iron chissel was heated red hot, and dropped into the water, one end being immersed and the other resting on the edge of the vessel. The gold leaf gradually open'd about an inch negatively, then closed and open'd positively, remaining positive to the end of the experiment. See plate 3. fig. 5.

EXPERIMENT II.

The chissel was heated more than in the last experiment, and the gold leaf struck the sides of the electrometer six times negatively, then it changed and stood at half an inch positive to the end.

EXPERIMENT III.

The chissel was again made very hot and it caused the gold leaf to strike often negatively, after which it closed, but never open'd positively.

EXPERIMENT IV.

The chiſſel was heated very much by blowing the fire, and it cauſed the gold leaf to ſtrike fourteen times negatively but no poſitive electricity appeared, this was repeated above twenty times without any production of poſitive electricity.

EXPERIMENT V.

Upon obſerving that the chiſſel was much calcined upon its ſurface, by being ſo frequently heated in the above experiment, I rubbed off the calx, and heated it again, and found that now it produced firſt negative and then poſitive electricity, as before; whence it appeared that its production of poſitive electricity depended upon the metallic ſtate of the iron.

EXPERIMENT VI.

A large bar of copper and a piece of braſs were heated red hot and plunged in the water, which alſo produced firſt negative and then poſitive electricity.

EXPERIMENT VII.

Melted lead was dropped into water contained in the baſon as above, which gradually opened the gold leaf poſitively.

EXPERIMENT VIII.

Melted lead being dropped into a deep narrow veſſel almoſt full of water did not electrify it, ſince it

it emitted no vapour, it is therefore not the mere decompoſition of the metal but the formation of a certain kind of vapour which excites electricity.

EXPERIMENT IX.

Boiling Mercury was dropped from an earthen crucible into a ſmall quantity of water in a porcelain cup ſtanding upon the cap of the electrometer which cauſed the gold leaf to open poſitively.

EXPERIMENT X.

Several thin pieces of bell metal were heated red hot and dropped into water, which cauſed a negative repulſion only.

EXPERIMENT XI.

An earthen unglazed flower pot was half filled with red hot cinders, then the other half was filled with chopped graſs, which cauſed the gold leaf to open with poſitive electricity, and to continue ſtriking the ſides a conſiderable time. In the ſame manner were tried cabbage leaves, lettuces, turnip tops and roots, and chick weed, with the ſame reſults.

EXPERIMENT XII.

Turnings of dry aſh wood were thrown upon the hot cinders as above, which ſmoked much without cauſing any repulſion of the gold leaf till water was added, which cauſed a ſtrong poſitive electricity.

EXP.

EXPERIMENT XIII.

Dry hay was burnt in the flower pot, as above, which produced no electricity till water was added, and then it became ſtrongly poſitive.

EXPERIMENT XIV.

The flower pot was placed upon the electrometer with red hot cinders alone, and water was dropped into the middle, which open'd the gold leaf negatively; then more water open'd it poſitively. The cinders were renewed, and water dropped in the middle open'd the gold leaf negatively, then dropped near the ſide open'd it poſitively, again in the middle negatively.

EXPERIMENT XV.

Since the cinders became both poſitive and negative with water only, I repeated the above experiments on green and dry vegetables with a red hot earthen crucible, but without any difference in the reſult. A ſquare piece of brick was firſt placed upon the electrometer, to prevent the heat from injuring it in this and all the ſubſequent experiments, in which red hot bodies were to be placed upon it.

EXPERIMENT XVI.

A ſpoonful of ſalt was thrown into the red hot crucible, which open'd the gold leaf negatively; a ſecond quantity was thrown in, and it became poſitive.

EXP.

EXPERIMENT XVII.

The crucible being again heated two ſpoonfuls of ſalt were thrown in, which open'd the gold leaf poſitively; then water was dropped into the middle of the ſalt, which changed its electricity to negative; then more water dropped near the ſide of the crucible open'd the gold leaf poſitively; then again in the middle negatively.

EXPERIMENT XVIII.

Salt and water were mixed and dropped into the red hot crucible, which cauſed a ſtrong negative repulſion; then after the water was evaporated more was dropped in the middle, which renewed the negative repulſion till the water was dropped near the ſide, when it became poſitive; this change from poſitive to negative was often repeated.

EXPERIMENT XIX.

A ſmall quantity of ſalt was thrown into the red hot crucible, which cauſed the gold leaf to open negatively; then the ſalt remained till it was burnt black, and water being added cauſed a ſtrong poſitive repulſion.

EXPERIMENT XX.

The vitriolic and nitrous acids were ſeverally dropped upon red hot bricks, which open'd the gold leaf poſitively. The bricks were tried before and after the experiments with water, which cauſed a negative repulſion.

EXPERIMENT XXI.

A large red hot cinder was placed upon the electrometer, and olive oil dropped upon it, producing a copious ſmoke, but no electricity, then water was added, which open'd the gold leaf negatively.

EXPERIMENT XXII.

Olive oil and water were ſhook together in a phial, and both poured upon a red hot piece of caſt iron about an inch thick, 4 inches broad, and 5 inches long, which open'd the gold leaf ſtrongly negative.

EXPERIMENT XXIII.

Vitriolic and nitrous acid were dropped upon the caſt iron, which open'd the gold leaf poſitively.

EXPERIMENT XXIV.

Dry hay was placed upon the caſt iron, and preſſed down by a ſtone placed upon it till it was burnt black, then water was added, which open'd the gold leaf poſitively. The hay was then bruſhed off, and more water dropped upon the iron, which cauſed the gold leaf to open poſitively, till the ſurface was well cleaned and heated again, when it produced negative.

EXPERIMENT XXV.

An heap of wheat flour was placed upon the hot iron, which ſmoked without any electricity, till water was added, which open'd the gold leaf poſitively.

EXP.

EXPERIMENT XXVI.

Sand placed upon the hot iron, and water added, open'd the gold leaf negatively.

EXPERIMENT XXVII.

Lump ſugar placed upon the hot iron produced no electricity till water was added to the burnt reſiduum, which open'd the gold leaf poſitively.

EXPERIMENT XXVIII.

Powder'd charcoal was placed upon the hot iron, and water dropped upon it, open'd the gold leaf poſitively: but when water was dropped upon a red hot piece of charcoal it cauſed a negative repulſion.

EXPERIMENT XXIX.

Red and white port wine dropped upon the hot iron produced negative repulſion when the iron was ſo hot as to produce no electricity with water alone, which was tried before and after the wine.

EXPERIMENT XXX.

Raſberry wine dropped upon the hot iron produced poſitive electricity. The raſberry wine and red port were alternately dropped upon the ſame iron five or ſix times ſucceſſively, which changed the electricity from poſitive to negative each time. Alſo ſeveral other ſweet wines were tried, which as well as ſugar and water produced poſitive electricity.

EXPERIMENT XXXI.

Fresh urine poured upon the hot iron produced strong positive electricity.

EXPERIMENT XXXII.

Milk poured upon the hot iron caused a strong negative repulsion, and even when water was added to the burnt residuum, except in some instances when it was burnt very black, it became weakly positive.

EXPERIMENT XXXIII.

Butter was burnt upon the hot iron, and water added caused a strong negative repulsion.

EXPERIMENT XXXIV.

Ale produced no electricity till water was added to the burnt residuum, which became positive.

EXPERIMENT XXXV.

Dry tea leaves were burnt upon the hot iron, and water added open'd the gold leaf positively, also black pepper and tobacco.

EXPERIMENT XXXVI.

Sope first burnt on the hot iron and then water added, also sope and water mixed produced a strong negative repulsion.

EXP.

EXPERIMENT XXXVII.

Tin-foil was placed upon the hot iron which ſoon melted, then water dropped upon it firſt open'd the gold leaf negatively, then weakly poſitive.

EXPERIMENT XXXVIII.

Alum burning on the hot iron produced no electricity till water was added to the burnt reſiduum, which cauſed a ſtrong poſitive repulſion.

EXPERIMENT XXXIX.

Moiſt ſalt of tartar was thrown upon the hot iron which cauſed the gold leaf to open ſtrongly negative, its vapours condenſed ſo quick upon the tube uſed for trying the electricity, that it was with ſome difficulty that it cou'd be excited.

EXPERIMENT XL.

Saliva produced poſitive electricity. When water alone was producing negative repulſion, ſpitting upon it wou'd immediately change it to poſitive.

EXPERIMENT XLI.

Yeaſt was ſtrongly poſitive, but not till water was added to the burnt reſiduum.

EXPERIMENT XLII.

Cotton and linen rags were burnt on the hot iron, and water added, produced a weak poſitive repulſion.

EXPERIMENT XLIII.

Sheep's wool, feathers, and hair, were burnt on the hot iron, and when a ſingle drop of water was added, the gold leaf ſtruck the ſides of the electrometer poſitively.

EXPERIMENT XLIV.

Raſped horn and bone were burnt upon the hot iron, which produced poſitive electricity when water was added, but not near ſo ſtrong as in the laſt experiment.

EXPERIMENT XLV.

Powder'd pit coal was placed upon the hot iron, which produced poſitive electricity upon the addition of water.

EXPERIMENT XLVI.

Freſh ſheep's blood was dropped upon the hot iron, which produced poſitive electricity.

EXPERIMENT XLVII.

A hollow piece of bell metal about an inch thick, and three inches diameter, was caſt on purpoſe to repeat theſe experiments upon, moſt of which were again tried, but with no remarkable difference, except that water produced negative electricity with more certainty. Upon the iron it was ſometimes negative, ſometimes poſitive, but moſtly none at all; whereas on the bell metal it was almoſt always negative.

EXP.

EXPERIMENT XLVIII.

Vinegar produced no electricity when dropped upon the hot bell metal, till water was added to the burnt refiduum, which caufed a ftrong pofitive repulfion.

EXPERIMENT XLIX.

The bell metal was at laft made too hot and therefore broke to pieces as it was taken out of the fire, I therefore again had recourfe to caft iron, and for the fake of its holding fluid fubftances, I turned a caft metal weight fo as to have a very fmooth concave furface in the middle, and a concave rim near the edge, fo that I cou'd place upon it feveral fubftances at once without mixing.

The lean part of a leg of veal was chopped fmall, and a fmall quantity placed upon the red hot caft iron, which caufed the gold leaf to open pofitively, but after burning fome time water was added, which changed its electricity.

EXPERIMENT L.

The fat of veal was burnt upon the hot iron, which produced no electricity till water was added, which caufed a ftrong negative repulfion both before and after it was burnt black.

EXPERIMENT LI.

Nitre was put upon the hot iron, which melted without producing electricity; then water was dropped upon it, which exploded without producing

any electricity; ſometimes ſmall globules of water floated a conſiderable time upon the melted nitre, and then ſuddenly exploded without ever producing any electrical repulſion or gradual evaporation, as is uſual with other ſubſtances.

EXPERIMENT LII.

Bees wax produced ſtrong negative electricity, with the addition of water.

EXPERIMENT LIII.

Verdegreaſe with water produced very weak poſitive electricity.

EXPERIMENT LIV.

Powder'd antimony ſmoked much, and when water was added the gold leaf open'd negatively.

EXPERIMENT LV.

Carraway ſeeds dropped upon the hot iron cauſed a ſtrong negative repulſion without the addition of water, alſo water added when they were burnt black open'd the electrometer negatively.

EXPERIMENT LVI.

Hemp ſeed thrown upon the hot iron cauſed a weak poſitive repulſion, but when water was added it became ſtrongly poſitive.

EXPERIMENT LVII.

A tea ſpoonful of water was dropped into the

con-

concave hot iron which did not produce any repulſion, then ſome powder'd gum arabic was added which cauſed the gold leaf to diverge poſitively, then bees wax was alſo added which cauſed it to become negative.

EXPERIMENT LVIII.

Theſe two laſt ſubſtances were dropped on the hot iron in the reverſed order which firſt produced negative and then poſitive.

EXPERIMENT LIX.

Muſtard ſeed was dropped upon the hot iron, which cauſed no repulſion till water was added to the burnt reſiduum, which open'd the gold leaf negatively.

EXPERIMENT LX.

Linſeed produced no electricity till water was added to the black reſiduum, which open'd the electrometer weakly negative. The iron was then made hotter, and the addition of water produced poſitive.

EXPERIMENT LXI.

Canary ſeed alſo produced negative by the addition of water till it was burnt very black and then it became poſitive: alſo aniſe ſeed, and fennel ſeed, were like the canary.

EXPERIMENT LXII.

Burnt millet ſeed produced poſitive electricity with the addition of water.

EXPERIMENT LXIII.

Water added to burnt coriander and cummin ſeeds, produced negative electricity till the reſiduum had continued burning a long time, and then it became poſitive.

EXPERIMENT LXIV.

Hitherto the electricity of the apparatus, whence the vapours aſcend, has been only examined. I now faſtened a piece of paper upon a bent wire, which being placed in the cap of the electrometer hung over the hot iron, ſo that the vapours in aſcending might paſs over the paper, and ſhew whether this electrical ſtate wou'd in any inſtance be of the ſame kind obſerved in the veſſel.

EXPERIMENT LXV.

The vapour of red port wine was tried as above and found poſitive, contrary to the ſtate of the iron in exp. 29.

EXPERIMENT LXVI.

The vapour of raſberry wine was found to be negative contrary to the ſtate of the iron in exp. 30. Alſo wine made from bilberries, and ſugar and water mixed, produced negative vapours.

EXP.

EXPERIMENT LXVII.

The vapour of pure water was poſitive, but the addition of a ſmall quantity of ſaliva changed it to negative.

EXPERIMENT LXVIII.

The vapour of raiſin wine was firſt poſitive and then negative, and the reverſe when the iron was examined.

EXPERIMENT LXIX.

As carraway ſeed produced negative electricity without the addition of water, and therefore without any viſible vapour except a little ſmoke, the paper fixed upon the electrometer was ſeveral times placed at different diſtances above the hot iron, whilſt the carraway ſeeds were burning, but no electricity appeared.

EXPERIMENT LXX.

The ſquare brick which ſupported the hot iron was placed in the middle of an earthen plate full of water, and ſtanding upon the electrometer, then the hot iron being laid upon the brick and out of the reach of the water, wool was burnt upon it, and a ſpoonful of water added; laſtly, the whole was cover'd with a glaſs jar with its mouth immerſed in the water that the vapour might not eſcape without touching the water; in this experiment no electricity appeared.

From

From theſe experiments it appears that various mineral, vegetable, and animal ſubſtances when evaporated, cauſe a poſitive or negative divergency of the electrometer, and it was remarked in the beginning of this ſection that M. de Sauſſure attributed theſe effects to the generation of a new quantity of the electrical fluid: but ſince the ſtate of the electricity of the aſcending vapour is contrary to that of the inſulated veſſel whence it riſes, it now ſeems more probable that the vapour thus produced acquires its poſitive or negative ſtate, becauſe its affinity with the electrical fluid is greater or leſs than that of the veſſel, and that when a particle of vapour is but juſt in contact with the ſurface whence it riſes, its capacity to become poſitive or negative is much greater than when it is entirely ſurrounded with air; and thus if the vapour becomes poſitive by abſorbing electricity from the veſſel, the veſſel will become negative and v. v. without the neceſſity of ſuppoſing a new quantity of the fluid to be generated in this proceſs.

SECTION V.

A deſcription of a doubler of electricity by which a very ſmall quantity of electricity may be augmented till it becomes ſenſible by common electrometers, or viſible in ſparks.

THE great importance of a machine for the purpoſe of detecting very ſmall quantities of electricity has occurred to many electricians, as by ſuch an aſſiſtant it is to be hoped that important diſcoveries may be made in the atmoſpheric electricity as well as in chemical experiments, wherein it may be ſuſpected that electricity is combined with other ſubſtances. And many curious and well contrived electrometers have been made from the time that Mr. Canton firſt uſed his pith balls, till Mr. Cavallo ſubſtituted fine wires and balls ſuſpended in a glaſs: but theſe as well as my gold leaf electrometer were incapable of diſcovering ſuch very ſmall communications of electricity as were made ſenſible by Mr. Volta's condenſer, which by means of a thin coated electric is capable of receiving a much greater quantity of the electrical fluid than a common inſulated conductor of the ſame dimenſion, which fluid becomes ſenſible by ſeparating the poſitive and negative ſides of the charged plate. On this ingenious contrivance Mr. Cavallo made a very conſi-

derable

derable improvement by transferring the electricity contained in the upper plate to another condenser of smaller dimension, as explained in the philos. trans. vol. 72.

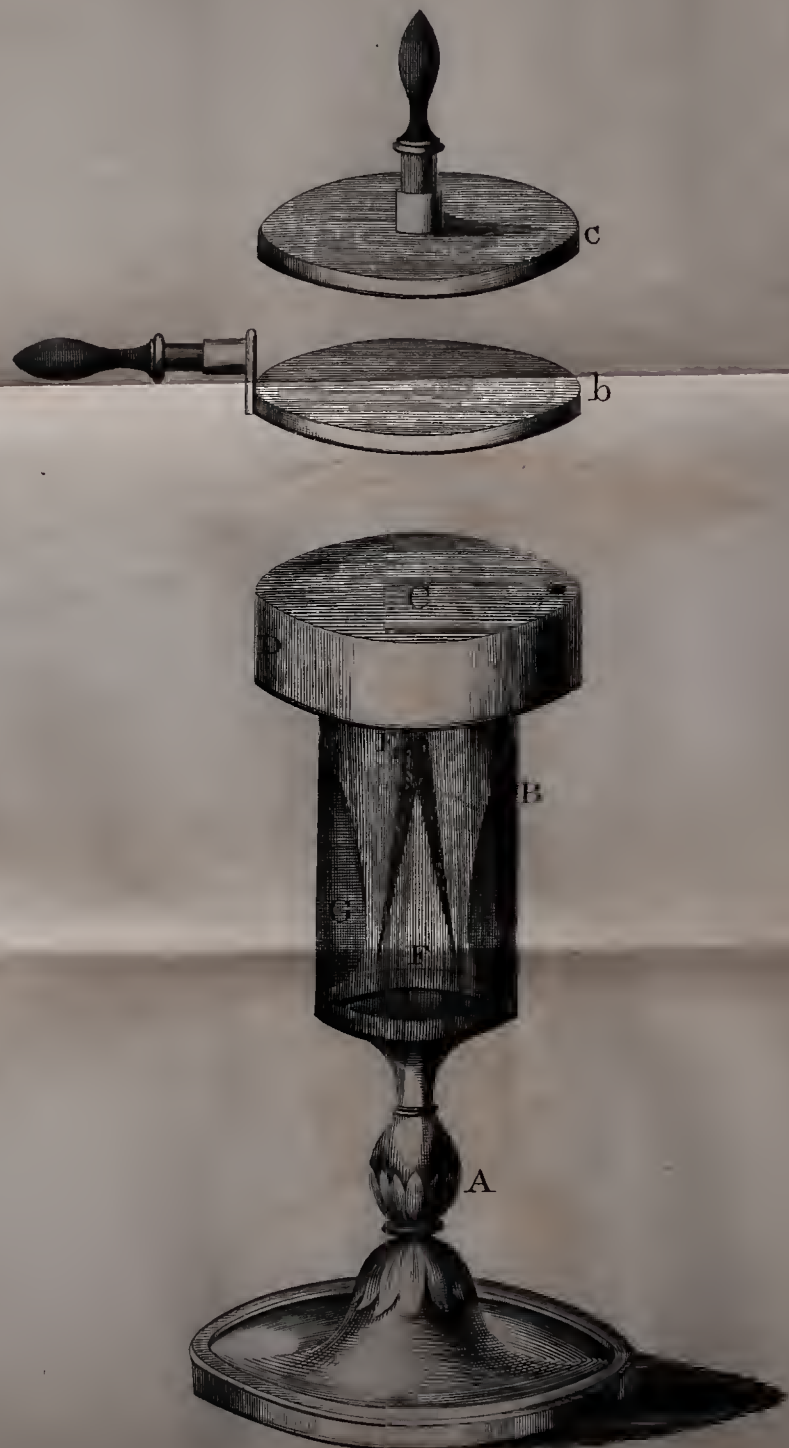
Yet notwithstanding the very great sensibility of this apparatus, atmospheric electricity cannot always be discovered by it, for instance, when the negative state of falling rain is nearly equal to the positive state of the air thro' which it falls.

The following instrument (which from its peculiar manner of augmenting small quantities of electricity I have named the electrical doubler) will render much smaller quantities of electricity sensible than the above-mentioned double condenser, unless the first condenser exceeds the dimension of the second as much as shall render its power equal to a given number of operations of the doubler, and so far they may be consider'd as the same instrument, for the doubler is only a condenser multiplying its capacity in geometrical progression: but this capacity augments so quick that a double condenser equal to its power at the twentieth operation must be 40 yards in diameter if the doubler and smaller condenser be only 2 inches.

The sensibility of the doubler was evinced by an electrico-meteorological diary kept for above a month, during which time I never failed to collect and distinguish atmospheric electricity. This diary I undertook at the request of my friend, Dr. Darwin, who hoped some important atmospheric discoveries might be made thereby, and which ac-

companied

Plate I



companied my deſcription of the doubler preſented to the Royal Society by the Dean of Lincoln, and printed in the philoſ. tranſ. vol. 77.

This inſtrument in its firſt and ſimpleſt conſtruction conſiſts of two poliſhed braſs plates with inſulating handles. The handle of one is fixed on the ſide of the plate, and the other on the middle, and ſtanding perpendicularly, ſee plate 1ſt.

The plates are varniſhed on the underſide, and the handles are made of mahogany, and fixed to the plates by inſulating nuts of glaſs cover'd with ſealing wax.

The method of collecting electricity from the atmoſphere, and continually augmenting it till it became ſenſible, was thus performed.

In dry weather I carried into the open air a lighted torch not liable to be eaſily blown out, or a ſmall lantern with a lighted candle in it, to the bottom of which was fixed by means of a ſocket an inſulating handle of glaſs cover'd with ſealing wax. In the other hand was carried a coated phial. Then elevating the flame a little higher than my head I applied it to the knob of the phial, holding it in this ſituation about half a minute. By this means I have found that more electricity may be collected than by an exploring wire inſulated and fixed to the top of a church ſteeple, as practiſed by F. Beccaria. Having thus collected a ſufficient charge I return'd into the houſe and applied the knob of the phial to the cap of the gold leaf electrometer, upon which I placed the plate (b) touching it with the forefinger

ſtretched

ſtretched over the inſulating nut; by this operation the electricity contained in the phial ſpreads upon the cap which ſerves as a condenſing plate, and electrifies the plate (b) contrarily, becauſe it is connected with the earth, and the varniſh is interpoſed as a charged electric. The phial being now removed and the forefinger lifted up, the plate (b) is ſeparated from the cap, and the plate (c) placed upon its upper ſide and touched by ſtretching a finger over the nut of its inſulating handle, this laſt plate is then electrified contrary to (b) and the finger being removed, and the plate (c) ſeparated from (b) it will be evident to electricians that the electricity of the cap and that of the plate (c) will be of the ſame kind, and nearly of equal quantity, ſo that the original charge is now doubled.

I then apply the edge of the plate (c) to the ſide of the cap, and placing (b) as before, and touching it again, the electricity of (c) as well as that of the cap, both act upon the plate (b) and the intenſity of its contrary electricity becomes equal to both; then removing (c) which comes away unelectrified; I take off my forefingers from (b) and lift it up, and placing (c) upon it I proceed as before, thus continuing to repeat this doubling proceſs till the gold leaf diverges ſufficiently to examine the quality of its electricity; or if the gold leaf be firſt taken out, the proceſs may be continued till ſparks appear.

In rainy weather the knob of the phial was applied to the inſulating handle of an umbrella, or to

a

a torch carried under it, and in this manner I continued to examine atmoſpheric electricity, till I conſtructed a more convenient apparatus deſcribed in ſection the eighth.

To prove that the electricity is doubled, it may be obſerved that the gold leaf opens to about twice the diſtance at each operation, and the application of the plate (c) to the ſide of the cap, or to a wire placed in it, does not diminiſh the divergency of the gold leaf tho' in this ſituation their electricity is diffuſed over double the quantity of ſurface, and admitting that the charge is doubled every time, which is not far from the truth whilſt the intenſity is weak, the twentieth operation will augment the firſt quantity of electricity above 500,000 times, and this proceſs even with a doubler in its original and moſt imperfect ſtate may be performed in leſs time than a minute.

SECT.

SECTION VI.

Improvements of the electrical doubler, with experiments made to discover the causes and obviate the inconvenience of its adhering or spontaneous electricity.

SOME time after the construction of my doubler of electricity described in the philos. trans. vol. 77, and in the above section, I found that on performing the doubling process a sufficient number of times, it always produced electricity without previous communication, even after every method likely to prevent it had been tried; yet this impediment was not so great as to render the instrument useless, for the adherent or spontaneous electricity in the beginning of the process, when the instrument was cautiously used, being very small, was easily overcome by that which was communicated in atmospheric experiments, and in case of doubt the atmospheric electricity was distinguishable by applying the bottle which collected it, to the two first plates alternately as mention'd in my description of the instrument.

However to deprive the doubler entirely of its adherent or spontaneous electricity, was thought a desirable circumstance, as its sensibility wou'd then be much greater, and consequently it might with more

more certainty be applied to the difcovery of new electrical facts, and which in this and the next fection I hope will be fufficiently proved.

Dr. Darwin, at the defire of Lord G. A. Cavendifh, made the firft attempt with two plates moving between two others by a lever, fo as to bring them exactly to the fame pofition in each operation. This contrivance he foon improved by another inftrument in which the plates ftood vertically and moved by rack work in a direction exactly parallel to each other. With this I tried whether the plates wou'd act without any refinous fubftance, and found that the interpofed air was a good fubftitute, and hoped that now fince it was not neceffary to varnifh the plates, nor bring them into contact, the fpontaneous electricity fuppofed to arife from the accidental friction of the plates wou'd not be produced. This inftrument was fent to Mr. Partington, and the improvement of placing the plates near together without varnifh was foon after mention'd to him in a letter.

That I might accurately try whether the inftrument wou'd be improved by this omiffion of varnifh, I made a doubler which confifted of three plates ftanding vertical and parallel, the middle plate fliding backwards and forwards between the two others. The connection between the two external plates was performed by lifting up the fliding handle, and the diftance of approach was adjufted by fcrews which ftopped the foot of the middle plate any where between actual contact and the fpace of

half an inch. When this doubler was completed and its inſulating pillars entirely deprived of adhering electricity by melting the ſurface of the ſealing wax which covered them, the doubling proceſs was tried, and it produced negative electricity at about ten operations, ſo that this inſtrument tho' free from all accidental excitement was yet poſſeſſed of ſpontaneous electricity. But when I counted the doublings and applied an inſulated candle to the firſt and ſecond plates alternately, I cou'd eaſily collect and diſtinguiſh atmoſpheric electricity in a ſmall room, tho' the doors and windows were ſhut, this I tried upon the ſuppoſition that the air would not be entirely deprived of its electricity by paſſing through ſmall openings.

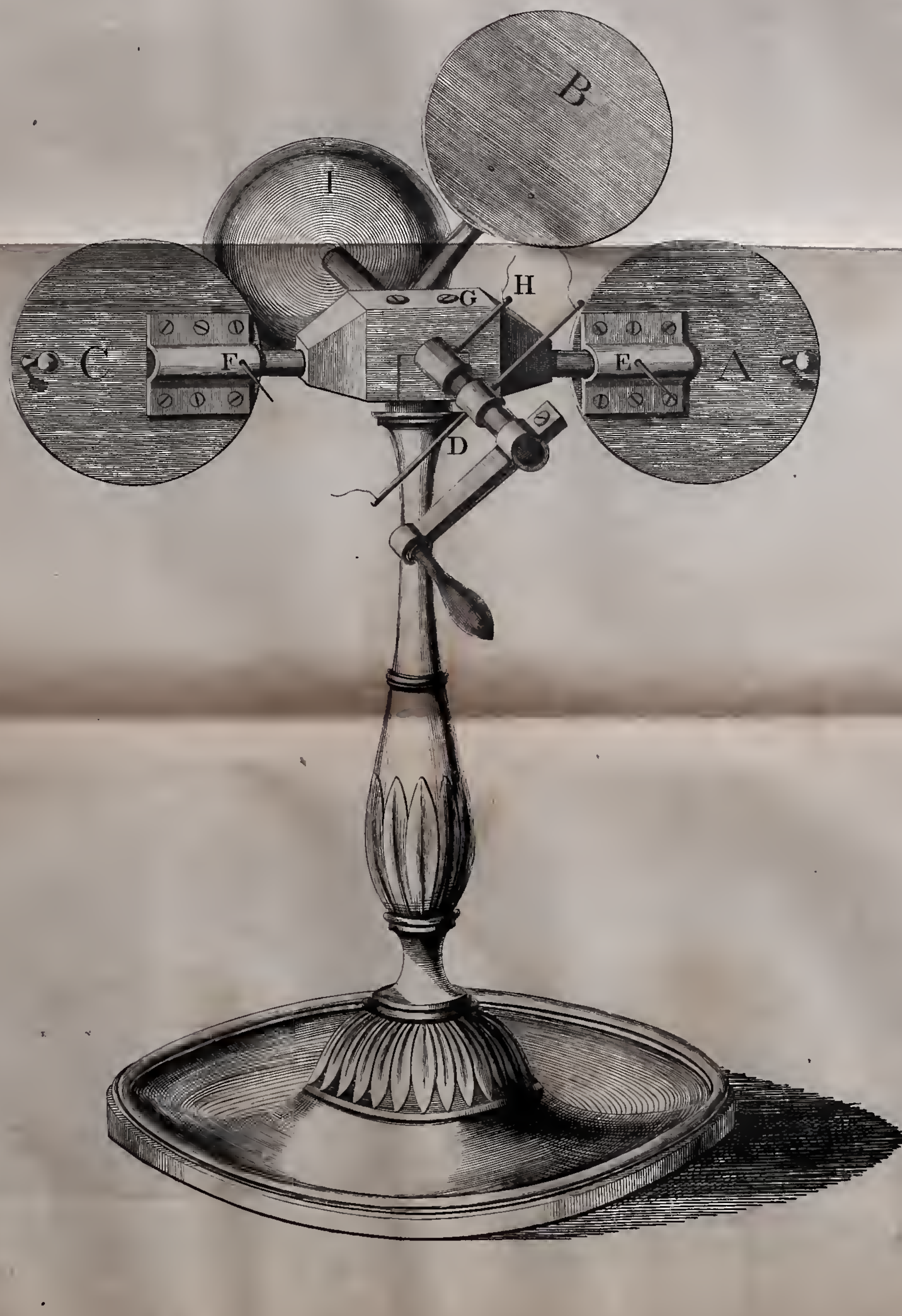
The next improvement I had in contemplation was a revolving doubler, and before I had finiſhed my contrivance, I was informed that Mr. Nicholſon had made one on the ſame principles, and intended to ſend it me, I therefore attempted nothing more till I received his very elegant and uſeful inſtrument, which is much the beſt mode of conſtructing my doubler hitherto attempted.

This doubler conſiſts of two inſulated and immoveable plates about two inches in diameter, and a moveable plate alſo inſulated which revolves in a vertical plane parallel to the two immoveable plates, paſſing them alternately. See plate 2.

The plate A is conſtantly inſulated and receives the communicated electricity. The plate B revolves, and when it is oppoſite the plate A, the

connecting

Plate II



connecting wires at the end of the crofs piece D muft touch the pins of A and C at E F, and a wire proceeding from the plate B muft touch the middle piece G, which is fupported by a brafs, wooden, or other conducting pillar in connection with the earth. In this pofition if electricity be communicated to the plate A, the plate B will acquire a contrary ftate, and paffing forwards, the wires alfo moving with it by means of the fame infulating axis, the plates are again infulated till the plate B is oppofite to C, and then the wire at H touches the pin in C, connecting it with the earth, and communicating the contrary ftate of electricity to that of B but of the fame kind with that of A. By moving the handle ftill further B is again brought oppofite to A, and the connecting wires joining A and C. they both act upon B. which is connected with the earth as before, and nearly double its intenfity, whilft the electricity of C is abforbed into A; becaufe of the increafed capacity of A, whilft oppofed to B, capable by its connexion with the earth of acquiring a contrary ftate fufficient to balance the influential atmofpheres of both plates.

Thus by continuing to revolve the plate B, the procefs is performed in a very expeditious and accurate manner.

The ball (I) is made heavier on one fide than the other, and fcrew'd upon the axis oppofite to the handle, to counterbalance the plate B, which may therefore be ftopped in any part of its revolution.

Yet notwithſtanding the convenience and accuracy of this doubler it always produced ſpontaneous electricity, even after all the reſinous ſubſtances uſed in its conſtruction had been melted over a candle, and after ſtanding a long time with its plates in connection with the earth. I therefore conjectured that this ſpontaneous electricity was not owing to accidental friction, but to the increaſed capacity of approximating parallel plates which might attract and retain their charge tho' neither of them were inſulated. To prove my hypotheſis I firſt endeavoured more effectually and ſpeedily to deprive the inſtrument of the electricity laſt communicated, and that I might know whether this ſpontaneous charge ſuppoſed to ariſe from the increaſed capacity of the parallel plates, wou'd be always of the ſame kind.

To effect this deprivation I connected the plates A and C together by a wire hooked at each end upon two ſmall knobs on the backs of the plates, the middle of the ſame wire touching the pillar which ſupports the doubler. Another wire was hooked at one end upon the back of the plate B, and at the other end to the braſs ball which counterbalances this plate. Thus all the plates were connected with the earth, and by turning the handle of the doubler, it might be diſcharged of electricity in every part of its revolution.

After often trying this method of depriving the doubler, I obſerved that its ſpontaneous charge was almoſt always negative. I then touched A and C with a poſitively charged bottle, and turned the doubler

doubler till it produced ſparks for a long time together; and after this ſtrong poſitive charge I hooked on the wires as above, and revolved the plate B about an hundred times, which ſo deprived the doubler of its poſitive electricity that when the wires were taken off, it produced a negative charge at about the ſame number of revolutions which it required before.

The poſitively charged bottle was again applied, and the wires being hooked upon the plates, as before, B was revolved only fifty times, yet this was found ſufficient to deprive it of its poſitive charge, and in many experiments five or ſix revolutions were ſufficient; but I never thought it ſafe to ſtop at ſo few, and have therefore generally turned the handle forty or fifty times between every experiment.

Leſt electricity adhering to the electrometer ſhou'd obſtruct the above experiments, I did not let it ſtand in contact with the doubler during its revolutions, but touched the plate A with the cap of the electrometer, after I ſuppoſed its electricity was become ſufficiently ſenſible: but leſt even this contact ſhou'd communicate any electricity, I made a cap for my electrometer of ſhell lac, having a ſmall tin tube in the center, to which the gold leaf was ſuſpended within the glaſs, and a bent wire was fixed to the top which might eaſily be joined to the plate A of the doubler, and thus the gold leaf was more perfectly inſulated, and the electricity cou'd

not be diffuſed over ſo large a ſurface. The glaſs which inſulates the plates and croſs piece of the doubler was alſo cover'd with ſhell lac.

The doubler and electrometer being now well inſulated, I proceeded to try the following experiments to aſcertain whether the ſpontaneous electricity was attracted by the approximation of uninſulated parallel plates.

EXPERIMENT I.

The doubler was deprived of electricity by revolving the plate B forty times with braſs wires hooked to all the plates, and during this deprivation the electrometer was connected with the plate A by means of a braſs wire. I then took off the wires whilſt the plate B ſtood between C and A, in the upper part of the plane of its revolution; and turning the handle towards the right hand, the gold leaf open'd negatively about a quarter of an inch, with twenty-one revolutions.

EXPERIMENT II.

The doubler was deprived of electricity, as before, and whilſt the plate B ſtood parallel to the plate A, the braſs wires were taken off, then turning the handle forwards, the gold leaf open'd a quarter of an inch negatively at the ſixteenth revolution.

Theſe experiments were repeated about thirty times, and on different days, without any conſiderable difference in the reſults; the number of revolutions

volutions being always greater when the plates ſet out from a ſingle poſition than when the wires were taken off whilſt A and B were parallel.

The plate B is placed at the diſtance of 1-16th of an inch from the other plates, and remains the ſame in the following experiments. It may be neceſſary to note this circumſtance, for doubtleſs the number of revolutions, if not other reſults wou'd vary, if the plates were placed nearer or farther aſunder.

EXPERIMENT III.

A copper plate thirteen inches in diameter having its ſurface rather convex, was furniſhed with an inſulating handle of oiled glaſs, four inches long and baked till the oil was well hardened. One end of the glaſs was fixed into a copper ſocket in the middle of the plate, and the other end into wood, that it might not be neceſſary to touch the electric part of the handle. This copper-plate was placed upon a mahogany table, and the doubler being deprived of its electricity, the plate B was placed parallel to A, ſo that B was connected with the earth, then the copper-plate was lifted up, by its inſulating handle, and applied to the plate A, and laſtly, the plate B being revolved only five times, the gold leaf diverged negatively to the diſtance of a quarter of an inch.

EXPERIMENT IV.

Leſt accidental friction againſt the mahogany table ſhou'd be objected, I lifted up the copper-

 plate,

plate, and after touching it with the point of a needle, I applied it to the doubler, as before, and found that the doubler did not produce its ſpontaneous electricity at leſs than 15 revolutions; then touching the plate again, I lower'd it till a part of its convex ſurface touched the ſurface of ſome water contained in a large diſh, and lifting up the plate, I applied it to the doubler, which cauſed the gold leaf to diverge negatively at five revolutions, as in experiment 3d.

EXPERIMENT V.

The plate B of the doubler was placed a little beyond its former poſition, ſo that its wire did not touch the middle piece, and conſequently tho' moſt of its ſurface was parallel to the plate A yet it was inſulated. The copper plate was then applied to B after it had touched the water as in the laſt experiment, and at the ſame time the plate A was touched by a braſs wire, to connect it with the earth. About five revolutions produced a very ſenſible poſitive divergency of the electrometer, as might be expected in conſequence of the negative charge being communicated to B inſtead of A.

EXPERIMENT VI.

By a frequent repetition of the foregoing experiments I was fully convinced of the attraction of electricity by approximating parallel plates: but hitherto the charge was negative, and ſuſpecting that other ſubſtances might have a poſitive affinity with the

the fluid, and eſpecially if my conjectures concerning projected powders and vapours were true; I therefore cover'd the ſurface of the copper plate with a mixture of gum water and minium, alſo with gum water and wheat flour, and found that theſe ſubſtances when dried upon the ſurface of the copper, changed its electricity, ſo that when it was applied to the plate A, as in experiment 3d, it produced a poſitive charge, and when applied to B, as in experiment 5th, it produced a negative charge, as might be expected if the painted copper plate by its uninſulated approximation to the ſurface of the mahogany table or water abſorbed a poſitive charge.

EXPERIMENT VII.

To render the electricity of approximating plates more conſpicuouſly ſenſible, I ground a braſs plate three inches diameter with emery till it would adhere to the ſurface of a piece of black marble. This plate and marble therefore conſtitute a condenſer in its original ſtate. The marble being moderately warmed I preſſed the braſs plate upon its ſurface with the point of a braſs wire, then liftng it up by its inſulating handle I applied it to the cap of the electrometer, which cauſed the gold leaf to ſtrike the ſide negatively.

I hope it will now appear evident by the precautions and experiments mentioned in this ſection, and from the known laws of electricity.

1ſt. That the doubler in its preſent ſtate may be deprived of accidental or communicated electricity.

2dly.

2dly. That the principal cauſe of its ſpontaneous charge, is the attraction of electricity by the approximation of its parallel plates.

3dly. That this charge may be poſitive or negative, according as the plates, or touching wires are compoſed of ſubſtances which have a greater or leſs adheſive affinity with the electrical fluid.

4thly. That the cauſes of ſpontaneous electricity are common to the condenſer both in its original and improved ſtate, and to the doubler, and equal in them all as far as they are equal in their dimenſions and powers.

5thly. That ſince the doubler may be compoſed of very ſmall plates, and yet its power be equal to that of a very large condenſer, its ſpontaneous electricity will be more eaſily overcome by a communicated charge than that of a condenſer of equal power, and therefore experiments performed with it will be leſs liable to equivocal reſults; and laſtly from theſe conſiderations I have ventured to preſume that the inſtrument may be advantageouſly uſed and applied to the diſcovery of new and intereſting facts in the ſcience of electricity.

SECT.

SECTION VII.

Experiments on the adhefive electricity of metals and other conducting fubftances.

HAVING fully proved by a frequent repetition of experiments, that the pofitive or negative fpontaneous charge of the doubler depended upon the abforption or repulfion of the electrical fluid by the approximation of its parallel plates, and that by applying larger plates covered with minium or flour, its electricity might be changed at pleafure, it eafily occurred, that if the fpontaneous electricity in the beginning of the procefs was fufficiently weak, the mere contact of metals or other fubftances having a different adhefive affinity with the electrical fluid might alfo change it, and a new and interefting employment for the doubler be difcovered.

This fuppofed effect of contact was confirmed by the following experiments, in which the doubler and electrometer were deprived of electricity, and ufed with the precautions and improvements mentioned in the laft fection.

EXPERIMENT I.

The fpontaneous charge of the doubler having been negative, and being deprived of this charge by the ufual method, the plate B was placed parallel

to the plate A, but ſo that B was not connected with the earth. The plate A was then touched with the blade of a knife, and the plate B at the ſame time touched with the point of a ſoften'd iron wire. With ſixteen revolutions the gold leaf diverged about one third of an inch poſitively.

EXPERIMENT II.

The doubler being deprived of electricity as before, and the plate B placed as in the laſt experiment, the knife was applied to B inſtead of A, and the ſoft iron wire to A inſtead of B, which opened the gold leaf negatively at 15 revolutions.

Theſe experiments were repeated very often, and the electricity changed each time, being always poſitive in the plate touched by the knife.

To diſtinguiſh ſo minute a difference of adheſive electricity, as that which might be ſuppoſed between two metals ſo nearly alike as harden'd ſteel and ſoft iron, wou'd appear incredible had not the frequent repetition of experiments confirmed it.

Being now well convinced of this fact I tried many other ſubſtances with various ſucceſs, ſometimes the charge wou'd change regularly for a long time together, by applying the oppoſed ſubſtances to A and B alternately, as in the above experiments; and ſometimes with other ſubſtances the charge wou'd be quite uncertain.

But to remedy the uncertainty of the influence of metals or other ſubſtances as far as poſſible, and to

to exhibit the effects of adhesive electricity to advantage, I made tables of experiments in which the substances to be tried as were applied to A or B are mentioned in the first and second columns, the number of revolutions in the third, and the state of electricity in the fourth.

The number of revolutions necessary to cause a divergency of the gold leaf sufficiently sensible, is by no means offer'd as an accurate measure of the strength of adhesive electricity, but at present I know of no better a way of comparing its effects.

TABLE I.

Lead Ore.	Lead.	Revolutions.	Electricity.
A.	B.	15.	P.
B.	A.	15.	N.
A.	B.	14.	P.
B.	A.	13.	N.
A.	B.	14.	P.
B.	A.	13.	N.
A.	B.	14.	P.
B.	A.	13.	N.
A.	B.	14.	P.
B.	A.	13.	N.

TABLE

TABLE II.

Lead.	Iron Wire.	Revolutions.	Electricity.
A.	B.	13.	N.
B.	A.	15.	P.
A.	B.	13.	N.
B.	A.	15.	P.
A.	B.	16.	N.
B.	A.	17.	N.
B.	A.	16.	P.
A.	B.	14.	N.
B.	A.	20.	N.
B.	A.	18.	P.

TABLE III.

Lead Ore.	Iron Wire.	Revolutions.	Electricity.
A.	B.	15.	P.
B.	A.	16.	N.
A.	B.	22.	P.
B.	A.	16.	N.
A.	B.	17.	P.
B.	A.	15.	N.
A.	B.	16.	P.
B.	A.	16.	N.
A.	B.	17.	P.
B.	A.	15.	N.

TABLE

TABLE IV.

Tin-foil.	Iron Wire.	Revolutions.	Electricity.
A.	B.	16.	N.
B.	A.	16.	P.
A.	B.	13.	N.
B.	A.	12.	P.
A.	B.	13.	N.
B.	A.	21.	N.
A.	B.	12.	N.
B.	A.	14.	P.
A.	B.	13.	N.
B.	A.	16.	P.

TABLE V.

Zinc.	Iron Wire.	Revolutions.	Electricity.
A.	B.	16.	N.
B.	A.	17.	P.
A.	B.	15.	N.
B.	A.	21.	P.
A.	B.	15.	N.
B.	A.	24.	P.
A.	B.	15.	N.
B.	A.	18.	P.
A.	B.	16.	N.
A.	B.	17.	N.
A.	B.	15.	N.
B.	A.	22.	P.
B.	A.	21.	P.
B.	A.	17.	P.

In

In the above five tables every experiment was made by double contact, and since the state of electricity was evidently changed, (except in a few instances) whenever the two opposed metals were applied alternately to A or B, there remained no doubt of the influence of these metals. Yet it was not very apparent whether it was the positive state of the one metal or the negative state of the other which prevailed. I therefore tried the effect of single contact, choosing two metals whose electricity appeared to be contrary, and touching A, C, and the cross piece, whilst B stood single in the upper part of its plane, with a positive metal in one experiment, and with a negative metal in the next, or, or applying the same metal to A, C, and the cross piece in one experiment, and to B in another, but in this last case B stood in the lower part of its plane. The reason of varying the position of B was, that the plate intended to acquire a contrary state to that produced by contact, might first be brought into connection with the earth; thus when A, C, and the cross piece had been touched, B came from its higher position into connection with the earth when brought parallel to A, and might then become contrarily electrified; and when B had been touched in the lower part of its revolution, C became connected with the earth when B was parallel to it.

TABLE

TABLE VI.

	Revolutions.	Electricity.
Lead ore applied to A, C, and the croſs piece, -	14. ———	P.
Zinc applied in the ſame manner	18. ———	N.
Lead ore, - - -	13. ———	P.
Zinc, - - -	15. ———	N.
Lead ore, - - -	16. ———	P.
Zinc, - - -	16. ———	N.
Lead ore, - - -	15. ———	P.
Zinc, - - -	14. ———	N.
Lead ore, - - -	14. ———	P.
Zinc, - - -	16. ———	N.

By experiments of ſingle contact in the above table, it now appears that the adheſive affinity of electricity to lead ore is poſitive, and to zinc negative.

TABLE VII.

In which zinc is again tried by applying it to A in the firſt ſix experiments, and to B in the ſix laſt, and alſo tried after the interval of ſeveral weeks when the air was much more dry.

Zinc.	Revolutions.	Electricity.
A.	12.	N.
A.	12.	N.
A.	11.	N.
A.	13.	N.
A.	10.	N.
A.	10.	N.
B.	13.	P.
B.	13.	P.
B.	15.	P.
B.	12.	P.
B.	12.	P.
B.	13.	P.

TABLE

TABLE VIII.

Lead ore applied to A and B alternately.

Lead Ore.	Revolutions.	Electricity.
A.	8.	P.
B.	19.	P.
B.	14.	P.
B.	24.	N.
B.	15.	N.
A.	8.	P.
A.	7.	P.
A.	10.	N.
A.	7.	P.
A.	7.	P.

From theſe experiments it appears that the adheſive electricity of the lead ore was not always ſo ſtrong as to overcome the ſpontaneous charge of the doubler.

Gold, ſilver, copper, braſs, regulus of antimony, biſmuth, tutenag, mercury, various kinds of wood, and ſtone, were tried by this method of ſingle contact and appear'd to cauſe a poſitive charge. Tin was negative, and a large piece of zinc much more weakly negative than a thin plate of the ſame metal uſed in the above experiments; of theſe I defer making tables till I have the opportunity of improving the accuracy of the doubler. This may be done ſeveral ways which I ſhall here deſcribe, hoping that ſome more experienced electrician will approve and execute them before I have leiſure.

1ſt. In the courſe of my experiments I found that the force with which the touching wires paſſed the pins on the back of the plates, had ſome influence on the charge, which was alſo obſerved by Mr. Nicholſon, and it may reaſonably be ſuppoſed that the adheſive electricity of theſe wires may have ſome effect. I wou'd therefore chuſe ſome metal which has the leaſt influence. Gold wire may probably be the beſt, and inſtead of ſmall wires to flirt againſt the pins, let ſtronger wires move a rowel like that of a ſpur, and let the cheeks in which the rowel is fixed be made to hold it harder or eaſier by means of a ſcrew paſſing thro' the center of the rowel. Thus the contact of the touching wires may be regulated by theſe ſcrews, and may perhaps ſo influence the ſpontaneous electricity, that either A or B may be made to prevail at pleaſure or be exactly balanced.

2dly. It is evident that the capacity of the plates is increaſed as they approach to each other, and this in-

increaſed capacity will in many experiments cauſe them to abſorb that kind of charge which agrees with their own affinities, or of the touching wires, inſtead of being influenced by the ſubſtances intended to be tried. Let the plate B be moveable upon its axis that it may eaſily be placed at any diſtance, between actual contact and the diſtance of half an inch from the other plates, that a diſtance may be found which will produce the leaſt ſpontaneous charge, and be more eaſily overcome by an intended delicate communication of electricity. It will be alſo neceſſary to regulate the diſtance on account of the dryneſs or moiſture of the air. In dry weather I have found the ſpontaneous electricity to become ſenſible at fifteen revolutions or under, and in moiſt air at about forty, the diſtance of the plates and contact of wires being the ſame in both.

3dly. The ſpontaneous charge of ſmall plates muſt be leſs than that of large ones, ſo that adheſive electricity communicated by ſingle contact will be more likely to overcome ſuch charge, for which reaſon principally, as well as for reaſons of convenience, ſmall plates are preferable; perhaps the ſize of a ſhilling wou'd be ſufficient.

4thly. The plates ſhou'd not be cover'd with varniſh or lacquer, leſt they ſhou'd retain electricity, and to prevent tarniſhing, the plates may be gilt, or made of the metal uſed for reflecting teleſcopes.

5thly. The ſpontaneous charge is produced at fewer or more revolutions according to the velocity or regularity with which the axis of the doubler is

 turned,

turned, ſo that a regular motion wou'd alſo add to the perfection of the inſtrument, which might be effected by means of a pendulum, and a vibrating doubler wou'd perform the proceſs as well or better than any other. The wires touching with equal force, and in regular time, wou'd be a conſiderable advantage with reſpect to the accuracy of experiments, and a doubler of this conſtruction might be made to continue its motion like a clock, ſo that inſulated veſſels containing chemical mixtures or growing vegetables, might be placed ſo as to receive its ſuperfluous electrictity, and be kept in a conſtant ſtate of electrification.

I will conclude this ſection with obſerving that ſince electricity, like all other known fluids, adheres with more or leſs force to different ſubſtances, it affords a ſimple and very ſatisfactory theory of the excitation of glaſs and other electrics, uſed in the conſtruction of electrical machines; for when the ſilk flap is rubbed by the revolving glaſs cylinder, it is brought into cloſe contact, and electricity adhering more forcibly to glaſs is carried forward into the open air, which air having not been render'd negative like the ſilk, does not counterbalance the ſurface of the glaſs, and therefore its capacity being leſſen'd, it emits the charge it had juſt abſorbed. The amalgamated cuſhion aſſiſts the proceſs by bringing a ſurface of a conducting quality and in connection with the earth into cloſer contact.

SECT.

SECTION VIII.

Obſervations on atmoſpheric electricity collected by the flame of a candle.

BEFORE I deſcribe my obſervations on this ſubject of enquiry, it may be proper to mention ſuch theory of atmoſpheric electricity as appears to me conſonant to the general operations of nature, and deduced from the moſt rational ſyſtems of others, my own obſervation, or the contents of the foregoing ſections, which the intelligent reader will eaſily apply to this purpoſe.

The intention of beginning with the theory is to give the reader, (who may not have attended to atmoſpheric electricity) an opportunity of ſeeing to more advantage the principles which theſe obſervations tend to confirm or illuſtrate, and thereby render them more intereſting and pleaſant.

Atmoſpheric electricity may be principally conſidered as it appears in two ſtates of the air, that is tranſparent and cloudy.

1ſt. The tranſparent or clear air always contains a great quantity of water in ſolution, and is generally found to be in a ſtate of conſtant poſitive electrification, yet not always of the ſame degree of intenſity, nor is the atmoſphere every where in the ſame ſtate, for the higher regions from their more perfect

insulation, are more strongly electrified than the lower strata of air whence the earth is constantly reabsorbing this fluid, and the invisible vapours are undoubtedly more or less dense in different places according to the quantity of evaporation and condensation, depending on the variations of heat and cold, so that irregular spaces of air, perhaps in the form of clouds, yet invisible, will be electrified positively or negatively; and to restore the equilibrium, the appearances called falling stars are produced. Or if the equilibrium between much larger tracts of air is to be restored, large meteors such as that of the year 1783 fly with astonishing brilliance and rapidity from one region of the air to another.

The aurora borealis is another electrical appearance frequently seen in a transparent atmosphere, yet it is sometimes seen when there are clouds, and is probably owing to the diffusion of electricity in the highest and most rarified part of the atmosphere, where the air is not sufficiently dense to exhibit the electrical fluid in the form of corruscations or balls of fire.

2dly. When vapours are sufficiently condensed to become visible, the intensity of their electrification increases, and if the clouds thicken speedily, their sensible electrical atmosphere sometimes extends to the distance of several miles. This extensive atmosphere will act powerfully on the lower strata of vapour, (which may be considered as having an imperfect connection with the earth) and induce a negative state whose intensity will continue

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increaſing with that of the ſuper-incumbent cloud, till the equilibrium be reſtored by tremendous claps of thunder, with vivid corruſcations of lightning. And if the cloud happens to be low, the earth itſelf becomes its immediate opponent, and is ſometimes violently ſtruck to the injury or deſtruction of its vegetable or animal inhabitants.

Theſe are the chief and moſt ſtriking effects of atmoſpheric electricity, and to account for them on the known principles of this fluid is the buſineſs of my preſent attempt.

The firſt and moſt difficult part of this inveſtigation is to aſcertain the general cauſe of ſenſible electricity in the air, and explain the particular manner in which it is abſorbed from the earth. But from the late ſatisfactory experiments of Meſſrs. Volta, Lavoiſier, De la Place, and De Sauſſure, the evaporation of water by the ſun's heat may be confidently aſſigned as the true general cauſe, and this opinion I hope the reader will find in ſome meaſure ſtrengthen'd by the experiments contained in ſection the fourth. And from the experiments on approximating ſurfaces, and on adheſive electricity in the ſixth and ſeventh ſections, I wou'd infer that when water is raiſed into the air by means of heat, electricity adheres more copiouſly under ſuch circumſtances to each riſing particle from the general laws of the attraction of coheſion, and the very great elaſticity of the electrical fluid; for a riſing particle of water may be conſidered as in the ſituation of the copper plate, ſection 6th, experiment 3d and 4th, that

is

is ſurrounded with air except that it is connected with the earth by one point of contact. And if there is a difference between air and water as to their elective attraction of electricity, which from numerous correſponding facts may eaſily be admitted, it follows that the ſmaller the particles of water are, the more they come into contact with air, that is their ſurfaces bear a greater proportion to their ſolidity, and conſequently they partake the more of the property of air as to their attraction of electricity; or the ſurface of air in contact with the water, has in this ſituation, the opportunity of abſorbing electricity thro' the above-mentioned touching point: which electricity from the circumſtances of approximation and contact, may be condenſed and the particle of water be poſitively electrified tho' uninſulated.

It is for the ſake of perſpicuity that the vapour is here conſidered as riſing in the form of ſmall globular particles: but however that may happen, the electrical adheſion will probably be the ſame: for if the proceſs of evaporation ſhou'd not conſiſt in the aſcenſion of globular particles raiſed by heat, but that it conſiſts in a chemical combination of heat, air, and water, which inſtantaneouſly form a tranſparent fluid, this compound ſubſtance may have a greater adheſive affinity with electricity than the ſurface whence it riſes, and therefore become poſitively electrified. And this laſt ſuppoſition is conſiderably illuſtrated by the experiments contained in ſect. 4th, wherein it is ſeen that the mixture of various mineral, vegetable, and animal ſubſtances, with

with the evaporating water changed its adhefive electricity.

Vapour thus afcending electrified, and being combined with air and heat fo as to form a perfectly tranfparent fluid, is in its weakeft pofitive ftate, till the heat paffes off either by diffufion in the circumambient air, by two currents of different degrees of rarity paffing in contrary directions, or by the higher part of the atmofphere moving with greater or lefs velocity than the lower, each current being more or lefs cold than the other. In any of thefe fituations the vapour will be condenfed and increafe the intenfity of its pofitive charge, and fome fuch caufes acting at all times, produce a conftant pofitive electrification of the atmofphere, even before the degree of condenfation is fufficient to deftroy its tranfparency.

During a fpace of fifteen years, F. Beccaria never obferved a ferene atmofphere to be negatively electrified, except in four inftances, when there was great reafon to believe it proceeded from the influence of diftant clouds. See his treatife on artificial electricity.

When this kind of condenfation happens in the higher and more infulated part of the atmofphere, where no equilibrium can be reftored by an infenfible diffufion of electricity, nor by ftriking fuddenly into the earth, and when the intenfity of this electricity is increafed beyond the capacity of the vapour to which it is attached, it is formed into balls of fire; for any fluid will form itfelf into a globular

figure

figure from its own attraction of cohesion, if this effect be not prevented by adhesion to other substances. These balls of highly condensed electricity then move off towards those parts of the air which are least electrified, diffusing electricity as they pass, till they are wholly dissipated and consequently disappear. This dissipation may be plainly distinguished by a train of fire which often follows the meteors called falling stars.

The same causes may be supposed to occasion the larger meteors, which being collected from and dissipated in more extensive regions of air, are more luminous, and attended with one circumstance which might be expected from a very great accumulation of electricity, that is a division of the ball into several parts towards the end of its course.

Whoever has seen electricity emitted from a large electrical machine, thro' a long and capacious exhausted tube of glass, may perceive a striking similarity between this experiment and the aurora borealis, and may reasonably conjecture that the electrical equilibrium being destroyed in the highest and most rarified part of the atmosphere is the occasion of this appearance, and that it is very high is proved by the converging direction of the streams; and since the streams sometimes appear to move about considerably, and to indicate an uncommon degree of electrification, I have frequently been induced to examine the state of the air with a very sensible electrometer, during a very luminous aurora borealis, but cou'd not distinguish either an extraordinary quan-

quantity or motion of electricity. Perhaps other ſituations might be more favourable for ſuch obſervations, and hence others have more confidently affirmed that their apparatus has been affected by it.

When the air has loſt more of its heat and the condenſed vapour becomes viſible ſo as to form clouds or miſts, the intenſity of its electrification is increaſed, becauſe the water is now formed into ſmall globules whoſe ſurfaces proportionally leſſen, as the globules increaſe in diameter, and from Dr. Franklin's experiment of the can and chain it has been long known that leſſening the quantity of ſurface expoſed to air, increaſes the intenſity of electrification. Miſts or fogs which are only thin clouds near the earth are generally found to be electrified ſtrongly poſitive, ſo that a kite having a metallic ſtring and raiſed in miſty weather will produce pungent ſparks. But when clouds fly over a tranſparent air, and are in a ſtill ſtronger ſtate of electrification, it often happens that their atmoſphere drives into the earth the electricity contained in the lower ſtratum of vapour, or that contained in ſome part of the cloud which from its ſituation can be moſt eaſily diſcharged thro' its imperfectly conducting connection with the earth.

A part of the cloud thus render'd negative is frequently ſeparated from the poſitive part, by the different currents of wind, or when the higher part of the cloud moves with more or leſs velocity than the lower, in this caſe the negatived vapour will pro-

produce a fenfible atmofphere, and hence the clouds appear fometimes pofitive and fometimes negative.

To illuftrate this effect of ftrong electrical atmofpheres, the reader may try experiment the 8th, fect. 2d. And that a negative atmofphere will become fenfible even upon a body floating in air whofe pofitive ftate is the only caufe of fuch atmofphere, is eafily tried by firft caufing the air of a room to be ftrongly electrified pofitively, and then a fmall flip of gold leaf thrown into the air will acquire a negative ftate as it leaves the hand, and will be repelled by the approach of a finger or other conductor. In this experiment the finger has a fenfible negative atmofphere as well as the gold leaf, tho' it be not infulated.

In fummer altho' the hygrometer indicates a drier air, yet there is undoubtedly more evaporation, and therefore more water combined with or diffufed in the atmofphere. The furface of the earth is hotter, and yet the higher part of the atmofphere, owing to its tranfparency and diftance from the earth is not heated in the fame proportion. In fhort every natural procefs is quickened or retarded by the active influence of the fun, and if vapours can now be more fuddenly raifed, they may alfo be more fuddenly condenfed, and under thefe and other favourable circumftances, the clouds become electrified to a much higher degree of intenfity, till the equilibrium of the differently electrified ftrata, is reftored by explofions termed thunder and lightning.

The

The concourſe of two oppoſitely electrified clouds has ſometimes been thought the immediate cauſe of thunder, and it is certainly poſſible that ſuch clouds may now and then be driven by oppoſite currents ſo as to cauſe an exploſion, but I think it is more agreeable to the moſt common appearances of the clouds to account for it by the extenſive and powerful influence of electrical atmoſpheres, whereby the ſeveral parts of the cloud or ſurface of the earth are render'd poſitive or negative, as explained above; for it will not otherwiſe be eaſy to account for the quick and frequent ſucceſſion of exploſions which are perceived in a ſingle and diſtinct cloud, every part of which is apparently moving in the ſame direction. But on the ſuppoſition of a negative ſtratum, occaſioned by a powerful poſitive atmoſphere, as long as a rapid condenſation of water takes place, ſo long may a repetition of exploſions be expected.

The following experiment may ſerve to illuſtrate the proceſs of atmoſpheric exploſions as far as relates to the influence of powerful electrical atmoſpheres.

Let two ſlips of gold leaf or rather white Dutch metal be faſten'd to a braſs ball ſuſpended by a ſilk ſtring, or other inſulating ſubſtance. Bring the braſs knob of a charged bottle towards the points of the metallic ſlips till they become charged with electricity, which will cauſe them to be repelled each way from the knob of the bottle and ſtand as in plate 3d, fig. 3d. Continue to hold the bottle in the ſame poſition during a few ſeconds, and one of the ſlips will bend towards the knob of the bottle

fig.

fig. 4, and ſtrike it ſuddenly, then it will ſtand repelled till its electricity be again diſſipated. In this manner it will continue to repeat the ſtroke as long as a ſufficient quantity of electricity remains in the bottle, unleſs the air be very dry, and then this experiment may fail, which with me has only happened twice.

After this ſhort account of my ideas of atmoſpheric electricity, I now proceed to deſcribe the inſtruments I have made uſe of in making obſervations.

The moſt common apparatus hitherto uſed has chiefly conſiſted of high pointed and inſulated conducting rods, or wires extending from the place of obſervation to the top of an high building or ſteeple, and connected with an electrometer, or the ſmall and inſenſible communications of electricity have been collected by means of Mr. Volta's condenſer. But theſe inſtruments are generally either not ſufficiently ſenſible, or they can only ſhew the ſtate of atmoſpheric electricity at intervals, whence the obſerver loſes the opportunity of watching the momentary and intereſting change which happens in ſeveral ſtates of the atmoſphere, eſpecially during the paſſage of thunder clouds.

In ſect. 2d, exp. 20th, 31ſt, and 32d, it was found that the flame of a candle was very uſeful in rendering the atmoſpheric electricity ſenſible when it could not be perceived by means of points; this I believe it does becauſe the effluvium of the candle, which is of a conducting nature, becomes combined

with

with air ſo as to form a very compleat union, and as the rarified air ſo combined with phlogiſtic effluvium riſes upwards, it is continually ſucceeded by a freſh quantity, and hence the apparatus has the opportunity of abſorbing electricity much more copiouſly than the ſharpeſt points. Conſidering this advantage I provided a deal rod about 10 feet long, (ſee plate iii. fig. 2d,) and after the ſmaller end was well dried it was faſtened into a long tinn'd iron funnel with cement, ſo that the funnel did no where come within half an inch of the end of the rod; by this means it is kept dry, and the funnel is not ſo liable to be accidentally broken off as if it was inſulated by means of glaſs. At the ſmall end of the funnel is ſuſpended the ring of a chain which ſupports a ſmall lantern, containing a lighted candle. To the lower and broad edge of the funnel a ſoftened braſs wire is faſtened, which is about the length of the whole rod, and at the lower end is hooked to a ſmall ring near the thick end of the rod, that the wire may not be liable to accidents when the inſtruments is taken down. When this apparatus is uſed, a window is opened in the higheſt room of the houſe, and the rod is placed upon one ſtrong nail and under another, on one ſide of the caſement, ſo that the lantern is elevated about 50 degrees. Near the place to which the rod is faſtened is a hole in the window frame of ſufficient width to receive a tube of glaſs cover'd with ſealing wax, on the end of which is a bent wire. The hook of the braſs wire is then taken from the ring, and hooked upon this

 inſu-

insulated bent wire, which stands at a proper height to be connected with the cap of a gold leaf electrometer, standing upon a board under the wire, and that the brass wire may not be too much agitated by the wind a ball of lead is hung upon it. In this situation it is plain that the atmospheric electricity collected by the candle will come down the brass wire and be communicated to the cap of the electrometer, or to any other instrument. But as it very seldom happens that the gold leaf does not diverge when this apparatus is elevated, there is little occasion to make use of a condenser or doubler, nor even of a candle when there are large clouds passing over or rain falling.

OBSERVATION I.

May 24*th*, 1787. Several heavy clouds passed from the N. W. and the above described apparatus being elevated, the gold leaf diverged sometimes positively and sometimes negatively; at last a blacker cloud approached and rain began to fall, which caused the gold leaf to strike the sides of the electrometer negatively with increasing velocity till a flash of lightning and clap of thunder happened, and at the instant of the flash the gold leaf suddenly started open and then closed, and gradually open'd positively striking the sides about ten times, it then slowly closed and open'd negatively, and again struck the sides with increasing velocity till the second flash caused the same convulsive motion and sudden change of

of its electricity; this was repeated ſeveral times during the paſſage of the cloud. When the thunder was more diſtant the opening of the gold leaf was leſs but yet very ſudden, and at laſt the gold leaf frequently ſtarted open when no thunder was heard, or flaſh ſeen.

OBSERVATION II.

May 26th, 1787. Several ſhowers paſſed over and electrified the apparatus firſt poſitively as the cloud approached, then it changed about the middle of the ſhower and ended negatively.

OBSERVATION III.

May 28th, 1787. The wind high and N. W. A ſhower of rain came on which electrified the apparatus firſt poſitively, the gold leaf continuing to ſtrike the ſides till the rain abated, then it became negative and it continued to ſtrike more ſlowly till the rain entirely ceaſed, when it again changed and ſtood at about a quarter of an inch poſitive, and the ſky became quite clear.

OBSERVATION IV.

June 7th, 1787. Wind S. W. and briſk. A ſhower coming on cauſed the gold leaf to ſtrike the ſides firſt negatively, then poſitively, and at the end of the ſhower again weakly negative.

OBSERVATION V.

June 8th, 1787. The ſky was entirely overcaſt and ſmall rain fell for ſeveral hours, which electrified the apparatus poſitively.

OBSERVATION VI.

June 25th, 1787. Wind W. Barometer 29. Thermometer in the houſe 64°. A little before one o'clock in the afternoon, the apparatus was elevated before the approach of a diſtinct and heavy cloud. The gold leaf diverged negatively ſlowly increaſing till it began to rain, it then ſtruck the ſides and continued ſtriking till the rain ceaſed, it then changed to poſitive and continued ſtriking whilſt fair; after ſome time it again became negative and ſtruck quicker whilſt it again rained, and ſome diſtant thunder was heard without moving the electrometer. Expecting more thunder, I hung up my watch near the apparatus that I might note down the time and changes of electricity, as they occurred during the paſſage of the cloud.

Hour.	Min.	
1	7	Raining, electrometer ſtriking quick negatively.
—	10	Electrometer ſtriking more ſlowly.
—	12	Now changed to poſitive & opening ſlowly.
—	13	Thunder heard, ſtriking ſlowly poſitive.
—	14	Very quick poſitive, yet raining.
—	15	More ſlowly poſitive.
—	17	Changing to negative.

Hour.	Min.	
1	18	Quick negative.
—	20	Thunder at a diſtance, ſtill ſtriking negative.
—	23	Still ſtriking negative, raining ſlowly.
—	26	Still ſtriking quick negative.
—	27	The gold leaf quite cloſed.
—	27½	Striking poſitively, yet raining ſlowly.
—	29	More ſlowly poſitive.
—	30	Rain ceaſed. Electrometer opening about an inch poſitively.
—	34	No ſenſible electricity. Some drops of rain falling.
—	39	Gold leaf open'd about half an inch poſitive, but decreaſing.
—	40	Suddenly open'd poſitive, and then ſlowly ſtriking. Heavy drops.
—	43	Decreaſing poſitively. Raining.
—	45	Electricity inſenſible. Raining ſlowly.
—	46	Slowly opening negatively.
—	47½	Slowly opening poſitively.
—	48	An inch wide poſitive.
—	49	The gold leaf agitated and poſitive.
—	49½	Still agitated but changed to negative.
—	50	Opening negatively by ſtarts till it ſtrikes quick. Raining faſt.
—	52	Ceaſes to ſtrike, decreaſing faſt.
—	53	Changed to poſitive.
—	54	Striking poſitively.
—	55	The gold leaf ſtruck the glaſs inſtead of the tin-foil.

Hour.	Min.	
1	56	Striking very quick pofitively.
—	57	Slower and then very quick, ftill raining very faft.
—	59	Diftant thunder. Changing to negative.
2	0	Striking quick negatively.
—	1	Decreafing negatively.
—	1½	Opening pofitively to the diftance of an inch.
—	2	Then changed to negative, and ftriking quick.
—	4	Changed to pofitive, and then ftriking quick.
—	6	Changing to negative.
—	7	Striking quick negatively.
—	8	Striking quick negatively.
—	9	Striking quick pofitively.
—	10	Still quick pofitively, and raining faft. Diftant fky brighter.
—	11	More flowly pofitive.
—	12	Again quicker pofitive.
—	13	Still quick pofitive. Sky clearing yet raining.
—	14	Decreafing pofitively.
—	15	Opening negatively. Rain flower and fky clearer.
—	16	Standing wide negatively.
—	16½	Decreafing negative.
—	18	Rain ceafed. Juft fenfibly pofitive.

2 18½

Hour.	Min.	
2	18½	Sun ſhining, and the gold leaf open'd to half an inch negatively.
—	20	A quarter of an inch poſ. Sky clear.

In this obſervation there are 10 changes of electricity in leſs than an hour and a half.

OBSERVATION VII.

July 2d, 1787. Wind N. W. Barometer 29. 45. Thermometer 68. Six o'clock in the evening. Unequal clouds covering the whole horizon, which cauſed a divergency of the electrometer of about half an inch poſitive.

OBSERVATION VIII.

Jnly 14th, 1787. About two o'clock in the afternoon. Wind N. E. Heavy ſhowers but clouds uneven. The gold leaf opened negatively, and moved irregularly till it ſlowly ſtruck the ſide, and as the rain abated it opened leſs, but never changed to poſitive.

OBSERVATION IX.

July 15th, 1787. About half paſt ſeven in the evening. Wind S. E. An heavy ſhower of rain falling, the gold leaf ſtruck the ſides quick poſitively, and continued to do ſo about 10 minutes; it then became weakly negative, and ſtood at half an inch negative when the rain ceaſed.

OBSERVATION X.

July 15*th*, 1787. About eight o'clock in the evening another ſhower came on which began to open the gold leaf poſitively, increaſing very ſlowly till it ſtruck the ſides whilſt the rain increaſed, and when the rain came down quickeſt, it gradually changed to negative. The clouds then appeared very uneven, and often changed the electricity till the obſervations were diſcontinued.

OBSERVATION XI.

July 17*th*, 1787. About 6 o'clock in the evening. Wind N. W. A ſhower of rain electrified the apparatus weakly negative during the ſpace of about half an hour without changing.

OBSERVATION XII.

July 25*th*, 1787. About one o'clock in the afternoon. Wind W. A heavy cloud approached and electrified the apparatus negatively a conſiderable time without rain; at laſt ſome drops falling the gold leaf ſtruck the ſides, and continued to do ſo till the rain ceaſed without changing to poſitive. The weather had been rainy for ſome days.

OBSERVATION XIII.

Auguſt 4*th*, 1787. Ten o'clock in the morning. Wind W. Barometer 29. 15. Sky very clear. The gold leaf opened juſt ſenſibly poſitive.

OBSER-

OBSERVATION XIV.

Auguſt 12*th*, 1787. Wind W. Barometer 29. 1. Therm. 62°. The ſky was overcaſt with uneven clouds, and a heavy cloud approaching it rained ſlowly, which gradually opened the gold leaf to the diſtance of an inch poſitively, then raining faſter it ſuddenly collapſed and changed to negative, opening to half an inch whilſt the rain ceaſed.

Two other clouds ſoon followed, which began poſitively and ended negatively as before.

A very extenſive cloud ſucceeded the laſt and open'd the electrometer poſitively, which continued ſtriking a ſhort time; then it changed and ſtruck negatively during about half the rain; it then changed and ſtruck poſitively during the remainder of the ſhower, and when the rain ceaſed it open'd about half an inch negatively, where it ſtood for a few minutes and then collapſed, the ſky clearing.

OBSERVATION XV.

About five o'clock the ſame day. The wind N. W. A ſhower began ſtrongly poſitive and ended negatively as before. About ſix o'clock ſome uneven clouds paſſed over and the electrometer diverged negatively without rain, then rain falling it ſtruck negatively a long time, then a heavier cloud approaching it changed and ſtruck very quick poſitively, till the rain abated and the cloud was nearly gone, when it again changed and was weakly negative till the rain entirely ceaſed.

OBSER-

OBSERVATION XVI.

August 14*th*, 1787. About noon. Wind S. W. Very extenſive clouds with ſmall drizling rain, the gold leaf opened about half an inch poſitively, which continued with very little variation about half an hour, it then rained ſomewhat faſter and the electricity changed and continued about the ſame time negative.

OBSERVATION XVII.

Auguſt 16*th*, 1787. Nine o'clock in the morning. Wind quite calm. A thick miſt. Electrometer open'd half an inch poſitively.

OBSERVATION XVIII.

Auguſt 18*th*, 1787. Half paſt twelve o'clock. Wind S. W. Thin white clouds had been paſſing over all the morning. A diſtinct black cloud approached and ſome rain fell before the apparatus was elevated, the electrometer open'd poſitively and continued opening but not ſtriking till very heavy drops fell, it then changed and ſtruck the ſides negatively till the rain ceaſed. Its velocity abated when it was fair, but continued ſtriking for about five minutes, it then decreaſed but continued open negatively till another cloud approached, it then open'd poſitively about half an inch, when it began to rain ſlowly, as the rain fell it open'd a little wider.

Hour.

Hour.	Min.	
12	45	About an inch poſitive. Rain ceaſing and gold leaf collapſing.
—	47	Electricity inſenſible.
—	47½	Opening ſlowly negative. Cloud approaching nearer.
—	48	A few large drops falling. Half an inch negative.
—	50	Still half an inch negative, but drops ceaſed.
—	51	Decreaſing. The clouds paſſed off, and another approaching.
—	57	Still juſt ſenſibly negative. Cloud large and likely to rain.
—	59	Beginning to rain. Opening to half an inch negative, and then ſtriking.
1	0	Raining faſter. Striking about twice in a ſecond.
—	1	Rain abated, yet ſtriking negatively.
—	4	Yet ſtriking negatively, but little rain.
—	5	More rain. Electricity decreaſing. Cloud about half over.
—	6	Electricity now increaſing.
—	6½	Striking negatively.
—	7	Striking quick negatively, yet but little rain.
—	8	Still quick negative. More rain.
—	10	So quick as to keep the gold leaf trilling againſt the ſides. Heavy rain.
—	12	Rain ſuddenly abating. Ceaſed to ſtrike, and decreaſing.

Hour.	Min.	
1	13	Changed to poſitive, ſtriking ſlowly then quick. Few drops.
—	14	Trilling poſitively.
—	14½	Slower poſitive. Very few drops of rain.
—	15	Quite fair, yet ſtriking ſlowly poſitive. Clear ſky over.
—	17	Yet ſtriking ſlowly poſitive.
—	19	Ceaſed ſtriking, and decreaſing. Sun ſhining.
—	20	Wide poſitive divergency, but decreaſing very ſlowly.
—	24	Half an inch poſitive.
—	25	Juſt ſenſibly poſitive.
—	27	Inſenſible. Sky clear.

Theſe clouds began and ended poſitively, and therefore it may be concluded that their proper ſtate was negative, which occaſioned on all ſides an influential poſitive atmoſphere.

OBSERVATION XIX.

Auguſt 25th, 1787. Twelve o'clock. Wind N. Barometer 28. 63. Having rained all day, the electrometer open'd weakly negative, and ſometimes changed to poſitive for a ſhort time, but was moſtly negative.

OBSERVATION XX.

Auguſt 27th, 1787. Two o'clock in the afternoon. Wind N. Barometer 29. 3. A ſhower came

came on which opened the gold leaf ſlowly poſitive, which continued opening and cloſing whilſt moſt of the rain fell, but did not ſtrike the ſide. When the rain was nearly over it changed to negative, and then ſtruck the ſides for a conſiderable time after the rain had ceaſed.

OBSERVATION XXI.

Dec. 18th, 1787. Eleven o'clock in the morning. Miſt covering the tops of the hills, which it had done for ſeveral days, ſometimes deſcending into the valleys. The gold leaf diverged ſtrongly poſitive: but upon the falling of ſome ſmall rain it was found negative. The ſame happen'd on the 20th.

OBSERVATION XXII.

Dec. 25th, 1787. Wind E. Small ſnow falling all day. Gold leaf diverged ſtrongly poſitive, tried ſeveral times.

OBSERVATION XXIII.

Dec. 27th, 1787. Wind N. E. Snow melting. A few white clouds. Electricity ſtrongly poſitive.

OBSERVATION XXIV.

Jan. 1ſt, 1788. Wind S. A very thick miſt, yet its electricity was but juſt ſenſibly poſitive, tho' whilſt the miſt was accompanied with froſt and with an eaſt wind it had been for ſeveral days ſo ſtrongly poſitive as to be very ſenſible without a candle.

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OBSERVATION XXV.

Jan. 2d, 1788. Wind S. Small rain. Electricity negative.

Jan. 6th, 1788. Wind S. Small rain. Electricity negative.

OBSERVATION XXVI.

Jan. 16th, 1788. High weſt wind. A cloud paſſed over and ſome ſleet fell. The electrometer diverged ſtrongly poſitive. The ſky then clearing it became ſtrongly negative, and decreaſing changed to a weak poſitive when the ſky was quite clear.

OBSERVATION XXVII.

Feb. 5th, 1788. Wind E. Thick miſt on the hills, with ſmall rain moſt of the day. Electricity negative except when the ſky appear'd brightening, it then became poſitive a ſhort time, and then when more rain fell it became again negative, and continued ſo moſt of the day. Conſtant rain ſeems moſtly negative, becauſe it probably forms a more extenſive connection with the earth by moiſture which weakens the poſitive and higher electricity, and ſtrengthens the influential negative atmoſphere.

OBSERVATION XXVIII.

Feb. 19th, 1788. Wind S. W. and gentle ſnow continued falling for ſeveral hours. The electrometer diverged about an inch poſitively.

OBSERVATION XXIX.

Feb. 20th, 1788. Wind E. No froſt but a very thick miſt. Gold leaf ſtruck the ſides poſitively.

OBSERVATION XXX.

March 5th, 1788. Wind S. W. and gentle ſnow continued falling from noon to five o'clock, the apparatus was elevated five times, and the gold leaf ſtruck the ſides poſitively.

OBSERVATION XXXI.

March 15th, 1788. Wind N. E. Snow had lain on the ground about a week, with hard froſt, but now it was thawing and there fell ſome ſleet. The gold leaf ſlowly ſtruck the ſides negatively.

OBSERVATION XXXII.

March 18th, 1788. Wind N. E. briſk. Overcaſt but fair. Electricity inſenſible with the candle, never obſerved ſo weak before.

OBSERVATION XXXIII.

March 21ſt, 1788. Wind W. One o'clock. A ſhower of hail came on which cauſed the gold leaf to ſtrike violently poſitive. A little before the ſhower ceaſed it changed and ſtruck negatively, and continued negative after the hail ceaſed and the ſun ſhone for more than half an hour, ſlowly decreaſing.

OBSERVATION XXXIV.

March 21*ſt*, 1788. Wind W. Three o'clock in the afternoon. A large cloud ſucceeded the laſt, the negative ſtate of the air having continued till the cloud approached, which changed the electricity to poſitive, when being engaged this cloud could not be examined. At four o'clock a very large cloud came with rain, the electricity was found ſtrongly negative, the electrometer could not come within 12 inches of its uſual poſition without endangering the gold leaf; towards the end of the ſhower it changed from negative to poſitive ſeveral times. Once the change only laſted whilſt the gold open'd and cloſed. At laſt it continued to ſtrike negatively whilſt the ſky cleared, decreaſing for about a quarter of an hour, it then changed to poſitive now fair, but a cloud approaching.

Hour.	Min.	
4	30	Electricity poſitive. Half open decreaſing.
—	31	Cloſed. The cloud approaching faſt.
—	33	Opening negatively. The edge of the cloud nearly over.
—	34	Still opening negative very ſlowly. No rain, very calm.
—	38	Little more opened. Cloud appears more broken.
—	41	Slowly decreaſing.

4 43

Hour.	Min.	
4	43	A few drops of rain. Gold leaf almoſt cloſed.
—	45	Quite cloſed. No rain. Sunſhines thro' a part of the cloud.
—	48	Still cloſed.
—	50	Opening poſitively. No rain.
—	56	Standing at half an inch poſitively.
5	0	Slowly decreaſing. Cloud appears heavier.
—	4	Quarter of an inch poſitive. No rain, cloud ſtill blacker.
—	9	Few drops of rain. Electricity the ſame.
—	17	No drops. Electricity rather increaſed. Cloud coming ſlowly.
—	19	Gold leaf diverges half an inch poſitive. No rain.
—	21	Gold leaf rather decreaſing.
—	23	Quite cloſed. No rain. Cloud heavy.
—	25	Opening negative. No rain.
—	26	Half an inch negative.
—	29	Rather wider. No rain. Cloud ſtill over.
—	30	Cloſed. Darker.
—	31	Opening poſitively.
—	32	Strikes ſlowly.
—	33	Striking quick poſitively, yet no rain.
—	34	Electrometer ſtrikes at twelve inches from the wire.
—	35	A little rain.
—	36	A clap of thunder, and ſudden ſtart of gold leaf, yet poſitive.

Hour.	Min.	
5	37	Raining faſter. Still poſitive.
—	38	Hailing faſt, ſtill poſitive, and ſtriking at twelve inches diſtant.
—	39	Remarkable ſtrong hail, ſtriking quick at twelve inches.
—	42	Still hailing. Electricity ditto.
—	44	Still large hail. Electricity weaker.
—	45	Changed quick to negative, and ſtriking at twelve inches diſtance.
—	46	Hail leſs. Electricity rather weaker.
—	47	Hail ceaſed. Electricity only opens negatively at three inches diſtance.
—	49	Fair. Electrometer in contact with the wire now poſitive.
—	50	Gold leaf juſt ſtrikes the ſides poſitively.
—	52	A flaſh of lightning and crack quickly following. A ſudden ſtroke of the gold leaf which changed it to negative.
—	54	Striking negatively.
—	55	Electrometer removed to the diſtance of 12 inches, where it ſtrikes quick negatively.
—	56	Striking more ſlowly negative.
6	0	Electrometer replaced ſtriking negatively. Still fair.
—	1	Striking rather ſlower.
—	3	Still ſlower, and yet fair.
—	5	Gold leaf ſtands about an inch wide negatively.

6 7

Hour.	Min.	
6	7	Clofed, and then opening pofitively.
—	8	One inch pof. Small rain falling.
—	9	Strikes the fides pofitively.
—	11	Decreafing. Rain ceafed.
—	12	Clofed. Quite fair.

The firft thunder clap did not change the electricity; the fecond changed it from pofitive to negative, contrary to former obfervations; this muft depend in fome meafure on the diftance.

OBSERVATION XXXV.

April 13th, 1788. Nine o'clock in the morning. Wind S. W. Sky perfectly clear having been without clouds fince the evening before. The gold leaf diverged about half an inch pofitively.

At twelve o'clock the fame day the divergency was only about a quarter of an inch, and the fame at eleven o'clock at night.

OBSERVATION XXXVI.

April 30th, 1788. The wind N. E. and very gentle. An hygrometer of whipcord, which moved in a fpace of 16 inches, marked in inches and eights moift and dry, reckoning up and down from the middle of the fpace, ftood at 6 $\frac{7}{8}$ dry. The apparatus was elevated at 3 o'clock, afternoon, and the gold leaf opened half an inch pofitively. At half paft 8 o'clock the hygrometer was rifen about an

 inch,

inch, and the gold leaf open'd ſo wide as nearly to ſtrike the ſide. The weather all the time quite ſerene. The falling of the dew appeared to increaſe the divergency of the gold leaf.

OBSERVATION XXXVII.

May 1ſt, 1788. Seven o'clock in the morning. Wind N. E. gentle, ſerene, and perfectly clear. The hygrometer 3 $\frac{7}{8}$ dry. The gold leaf nearly ſtruck the ſide poſitively.

About 11 o'clock the ſame day, hygrometer 5 $\frac{3}{8}$ dry, the gold leaf now opened only half an inch poſitively, ſtill clear and hot.

At 12 o'clock the wind changed to S. W. yet very clear and hot. The divergency was leſs than quarter of an inch. Hygrometer 6 $\frac{3}{8}$ dry.

At 1 o'clock, the wind S. Divergency 1-16th of an inch.

At 2 o'clock the electricity quite inſenſible, clear, and very hot. Hygrometer 7 dry.

At 3 o'clock the gold leaf open'd $\frac{1}{8}$ of an inch poſitively. A few white clouds appear'd. Hygrometer 7 $\frac{3}{8}$ dry.

At 5 o'clock, clouds ſomewhat darker. Divergency quarter of an inch. Hygrometer 7 $\frac{3}{8}$ dry.

At

At 7 o'clock, fewer clouds, very calm. Divergency half an inch. Hygrometer $6\frac{1}{8}$ dry.

Half paſt 8 o'clock. Hygrometer 5 6-8ths dry. Divergency only quarter of an inch. Sky now clear.

Eleven o'clock at night. Hygrometer 5 6-8ths dry. Clear and calm. Divergency half an inch.

OBSERVATION XXXVIII.

May 5th, 1788. Half paſt 4 afternoon. Wind N. E. Having been clear all day. Hygrometer 6 4-8ths dry. Divergency $\frac{1}{4}$ inch poſitive.

At nine o'clock in the evening, Hygrometer $5\frac{5}{8}$ dry. Barom. 29. 3. Clear and calm. The gold leaf ſlowly ſtrikes the ſides poſitively.

OBSERVATION XXXIX.

May 6th, 1788. Near twelve o'clock at night. Barom. 29. 2. Hygrometer $5\frac{3}{8}$ dry. An heavy ſhower of rain laſted about half an hour, during which the gold leaf continued ſtriking poſitively, and after the rain ceaſed it continued a long time ſtriking poſitively, and never changed to negative. Since the weather had been ſo long dry, it is probable that the air was not ſufficiently moiſt to conduct away the electricity, which wou'd have been otherwiſe repelled by the atmoſphere of the cloud.

OBSERVATION XL.

May 17*th*, 1788. The wind N. E. whence it had blown above a week without rain. Hygrometer 5 dry. Barom. 29. 2. The air undoubtedly very dry. The ſlips of Dutch metal were ſuſpended in the middle of a room as before deſcribed, and when the charged bottle was preſented the ſlips of metal ſtood diverging and cou'd not be made to ſtrike the knob as uſual, which ſhews that a certain degree of moiſture in the air is neceſſary to this experiment.

OBSERVATION XLI.

May 19*th*, 1788. Barom. 29. 15. Hygrometer 5 dry. Clouds moving ſlowly from the north and thickening in the ſouth. at half paſt 2 o'clock the apparatus was elevated, and the electrometer ſtruck the ſides ſlowly poſitive for ſome time, then ſtood ſtill at about an inch wide, and then ſtarted cloſer or wider ſeveral times, which was probably occaſioned by diſtant thunder.

Hour.	Min.	
2	45	A ſudden change to negative, which open'd half an inch, and then cloſed and became poſitive.
—	50	Opening and cloſing poſitively. Darker in the ſouth.
—	55	About quarter of an inch poſitive.

2 56

Hour.	Min.	
2	56	Suddenly ſtruck the ſide poſitively. and then ſtood at $\frac{1}{3}$ of an inch.
—	57	Cloſed.
—	58	Very ſlowly opening negative. More clouds.
—	59	An inch wide negative.
3	0	Suddenly collapſed, and then ſtruck the ſides negatively.
—	2	Strikes ſlowly negative.
—	3	Suddenly poſitive, then cloſed and open'd negative.
—	4	Cloſed ſuddenly, and then again open'd negative.
—	5	Suddenly changed to poſitive, and then cloſed and open'd negative.
—	6	Suddenly changed to poſitive, and then ſtriking negatively.
—	7	Diſtant thunder heard, and the changes of electricity were ſo quick that they could not be dictinctly noted.
—	15	A flaſh of lightning.
—	17	Another flaſh, and change from negative to poſitive, and at the ſame inſtant a loud clap.
—	18	A flaſh, and inſtant change from negative to poſitive.
—	19	Flaſh and inſtant change.
—	20	Flaſh and clap, ſudden cloſing, but no change to poſitive.

Hour.	Min.	
3	25	Sudden change to poſitive, which continued ſome time, then gradually changed to negative. Darker but no rain.
—	27	Sudden change to poſitive.
—	30	A very ſlow change from negative to poſitive. Beginning to rain.
—	31	Striking quick poſitively.
—	32	Thunder heard. Cloſing, then ſudden opening poſ. Rain ceaſed.
—	35	Flaſh. Sudden cloſe without changing, more rain. Negative.
—	37	Flaſh and ſudden change to poſitive.
—	45	Heavy rain. Slowly opening poſitively.
—	46	Striking ſlowly poſitive. Raining faſt.
—	50	Sudden change to negative, and thunder heard.
—	55	Standing negative, then ſuddenly ſtriking negative, and preſently again ſtopping without changing. Diſtant thunder. Rain ceaſed.
4	0	Opening ſlowly negative with a waving motion till it ſtrikes.
—	10	Still waving negative. No rain. Sky cover'd with cloud.
—	15	A little rain. Changing ſlowly to poſitive.
—	22	Rain ceaſed, ſtill poſitive without a waving motion.

4 30

Hour.	Min.	
4	30	Changed ſlowly to negative, without any perceptible change of weather.
—	35	Several changes without rain, except at the diſtance of two miles.
—	38	Another change to negative.
—	43	Small rain, ſtill negative.
—	48	Slowly raining; ſtriking negative; then waving and ſtarting.
—	50	Raining faſter, ſtill ſtriking negatively.
—	52	Diſtant thunder, without changing the electricity.
—	54	Raining faſt, ſtill negative.
5	0	Still raining faſt, and electricity negative.
—	1	Suddenly changed to poſitive. Rain abating.
—	2	Rain ceaſed, ſtill poſitive.
—	4	Fair, and gold leaf ſtriking poſitively. Sky clearing.
—	10	Still clearer. Poſitive electricity decreaſing.

OBSERVATION XLII.

May 24*th*, 1788. Ten o'clock at night. Barometer 29. 05. Hygrometer 6 dry. Very calm and clear, with a very bright aurora borealis. The atmoſpheric apparatus was carried into a field, and the electrometer conſiſted of a needle and a ſpider's thread, with a very ſmall bit of gold leaf faſten'd to one end and both the needle and ſpider's thread

were

were ſuſpended by means of the peg to which the ſlips of gold leaf were uſually faſtened. The ſame apparatus was alſo elevated in its uſual place, but tho' the ſpider's thread open'd ſlowly and ſtruck the ſides poſitively, yet no agitation or other motion happened, by which the electricity of the aurora borealis could be diſtinguiſhed from the common electricity of ſerene air.

OBSERVATION XLIII.

May 25*th*, 1788. Eleven o'clock at night, quite calm and clear, a little appearance of aurora borealis. Barom. 29. 06. Hygrometer 7 $\frac{7}{8}$. The ſpider's thread ſtrikes the ſide, but not ſo often as the evening before.

OBSERVATION XLIV.

July 4*th*, 1788. A large cloud cover'd the horizon, and it continued raining about two hours, during which time the funnel without its lantern was elevated, and the gold leaf changed its electricity ten times, beginning and ending poſitively.

OBSERVATION XLV.

July 5*th*, 1788. Large dark clouds frequently paſſed over; therefore about 2 o'clock in the afternoon a kite was raiſed, with a ſoften'd braſs wire in the ſtring about 200 yards long. When the kite had been flying about an hour, a dark cloud appeared at a great diſtance, and changed the electricity

city from poſitive to negative, which increaſed till the cloud came nearly over, and ſome large drops of rain fell, and to ſecure the ſtring from being wet I endeavoured to tie it on the oppoſite ſide of a poſt to which it was before faſtened; but when my hand came near the ſtring I received ſo ſevere a ſhock that my arm was deprived of ſenſation during a few ſeconds, and I was obliged to let the ſtring go, firſt terrified at the ſuppoſed loſs of my left arm, and then gratefully rejoicing to feel the returning ſenſibility after rubbing with the other hand. The exploſion was heard at the diſtance of about 40 yards like the loud cracck of a whip. The kite was raiſed often before and ſince this time, but without any remarkable appearance.

OBSERVATION XLVI.

July 30th, 1788. Ten o'clock at night. Barometer 29. 5. Hygrometer 4 6-8ths dry. The ſky clear and very calm. The aurora borealis very bright. The apparatus with an electrometer made of a ſpider's thread, was elevated, but no irregular motion, or extraordinary quantity of electricity was perceived.

OBSERVATION XLVII.

Auguſt 16th, 1788. About 12 o'clock. Wind S. W. A large and well defined cloud paſſed over, which as it approached open'd the gold leaf poſitively; when about half over it changed and became

came negative whilſt very heavy drops of rain fell. The gold leaf continued ſtriking negatively to the end of the ſhower, and then continued diminiſhing about 20 minutes after the rain ceaſed.

OBSERVATION XLVIII.

Auguſt 24th, 1788. Between 1 and 2 o'clock, afternoon. Barometer 29. 02. Thermometer 62°. Hygrometer 6 dry. Two clouds paſſed over, but not quite perpendicularly, and the electricity was wholly negative, and continued negative during the intervals; a third paſſed ſome what nearer and began negatively, but ended poſitively; a fourth came ſtill nearer and blacker, which began and ended wholly poſitive. No rain fell during the paſſage of the laſt, and only a ſmall quantity whilſt the two firſt were paſſing.

OBSERVATION XLIX.

Auguſt 25th, 1788. Between 10 and 12 o'clock in the morning. Barometer 29. 02. Therm. 60. Hygrometer 5 6-8ths dry. Two clouds paſſed on one ſide, which electrified the apparatus negatively; a ſmall quantity of rain fell, and more at a diſtance; a third cloud came directly over, and then the gold leaf open'd poſitively till it was about half over, and then it became negative without rain.

OBSERVATION L.

Jan. 13*th*, 1789. Eleven o'clock in the morning. Wind E. Barometer 28. 8. Thermometer on the north ſide of the houſe 26 degrees. Hygrometer 1 ½ dry, having been froſty and the ground cover'd with ſnow for ſeveral weeks. The wind now ſtrong and ſnowing faſt. The gold leaf continued ſlowly ſtriking the ſides poſitively. Another obſervation was made during a ſhower of ſnow which I omitted to note down, but found ſeveral changes from poſitive to negative as in ſhowers of rain.

FINIS.